Compensatory Mitigation and Stream Restoration Plan for Upper Cane Creek & Commissary Branch

Volume 1 of 2

April 2009

PREPARED FOR:
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Compensatory Mitigation and Stream Restoration Plan for Upper Cane Creek & Commissary Branch

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January 2009

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Prepared for Kentucky Department of Fish & Wildlife Resources

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January 2009

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EXECUTIVE SUMMARY

As part of their in-lieu fee agreement, the Kentucky Department of Fish & Wildlife Resources (KY Fish & Wildlife) proposes to conduct stream restoration and enhancement in the Upper Cane Creek watershed near Bowen in Menifee County, Kentucky. The project area, which borders the Daniel Boone National Forest, includes the restoration and enhancement of approximately 5,949 linear feet of the Right Fork of Upper Cane Creek and Commissary Branch, and their associated tributaries. The Right Fork of Upper Cane Creek flows into Upper Cane Creek located within the Red River basin of the Kentucky River. Commissary Branch flows into Right Fork of Upper Cane Creek at the most downstream end of the project area.

The mitigation approach will include a combination of restoration and enhancement. The approach will include relocating a county road (County Road 208) onto an adjacent upland area, due to the negative impacts the road is having on the Right Fork of Upper Cane Creek. As a result of the relocation, there will be one permanent ephemeral stream crossing on a tributary of the Right Fork of Upper Cane Creek. This impact will be compensated for by offsetting the impact with Ecological Integrity Units (EIUs), which are generated using the Eastern Kentucky Stream Assessment Protocol. In addition to relocating the county road, KY Fish & Wildlife is proposing to reclaim a paralleling ATV/logging road along Commissary Branch.

<u>Goals and Objectives</u>

The objective of this Mitigation Plan is to provide a functional and structural lift at the proposed restoration and enhancement site by:

- Meeting guidelines provided in the Mitigation Rule (EPA & USACE; 2008);
- Providing Ecological Integrity Units as prescribed in the EKSAP protocol;
- Restoring geomorphically stable conditions, such that the correct stream type is in the appropriate valley type;
- Restoring headwater drainage ways by designing channels to only transport the bankfull flow and create appropriate bedforms for aquatic habitat, while also providing riparian corridors;
- Improve headwater functions along the Right Fork of Upper Cane Creek, downstream to Cane Creek. A combination of restoration and enhancement mitigation measures will be implemented throughout the watershed to accomplish this goal. Restoration and enhancement efforts will provide functional lift by:
    - Reducing the sediment load in receiving streams through stabilization of streambanks and filtering of overland flows through riparian areas;
    - Improving habitat through improved substrate and in-stream cover, adding woody debris, restoring riparian habitat and its adjacent corridors, and improving natural aesthetics;
    - Improving pathways for flora and fauna by restoring and enhancing intermittent corridors within the headwater drainage ways.

<u>Mitigation Approach</u>

Eastern Kentucky Stream Assessment Protocol

KY Fish & Wildlife applied the Eastern Kentucky Stream Assessment Protocol at each of the restoration, enhancement, and impact sites located within the project area. The Eastern Kentucky Stream Assessment Protocol provides an estimate of the ecological integrity of a headwater stream ecosystem relative to reference stream conditions in the same region. The output of the model ranges from 0 – 1, and is calibrated such that a score of 1.0 is given for stream conditions indicative of least disturbed or reference streams in the region.

Results from the Eastern Kentucky Stream Assessment Protocol demonstrate that the restoration and enhancement efforts implemented at the project provide a functional lift of 1,297 EIUs (Table ES 1.1).

Table ES 1.1
Proposed Impact & Mitigation Sites, EIU Summary

Reach	Pre-existing Conditions			Predicted Conditions			Functional Lift
	Length (ft)	EII	EIU	Length (ft)	EII	EIU	Difference in EIUs
Proposed Impact Areas							
RUT1 of Right Fork of Upper Cane Creek - Road Crossing	47	0.55	26	47	0	0	-26
Proposed Mitigation Areas							
Right Fork of Upper Cane Creek - Reaches 1 & 2	1,740	0.77	1,340	1,562	0.98	1,531	191
Right Fork of Upper Cane Creek - Reaches 3 & 4	1,565	0.59	923	1,545	0.87	1,344	421
RUT1 of Right Fork of Upper Cane Creek	45	0.55	25	45	0.72	32	7
LUT1 of Right Fork of Upper Cane Creek	43	0.50	22	43	0.62	27	5
SUBTOTAL	3,393	--	2,310	3,195	--	2,934	624
Commissary Branch - Reaches 1 & 2	2,372	0.69	1,637	2,427	0.94	2,271	634
Commissary Branch - Reach 3	240	0.69	166	240	0.90	215	50
RUT1 of Commissary Branch	21	0.55	12	21	0.68	14	3
RUT2 of Commissary Branch	28	0.55	15	28	0.78	22	7
LUT1 of Commissary Branch	38	0.58	22	38	0.72	27	5
SUBTOTAL	2,699	--	1,852	2,754	--	2,549	699
TOTAL	6,092		4,162	5,949		5,483	1,323
NET GAIN	NA	NA	NA	5,902	NA	NA	1,297

Linear Feet

In addition to the Eastern Kentucky Stream Assessment Protocol, which demonstrates off-set on a structural and functional basis, KY Fish & Wildlife has provided a summary of total linear feet provided at the project area, which includes the offset of linear feet from the permanent ephemeral stream crossing (Table ES 1.2).

Table ES 1.2
Linear Feet Inventory

Proposed Impacts	Linear Feet	Acres
RUT1 of Right Fork of Upper Cane Creek – Road Crossing	47	0.004
TOTAL DEBIT	47	0.004
Proposed Mitigation		
Right Fork of Upper Cane	3,107	0.556
RUT1 of Right Fork of Upper Cane	45	0.007
LUT1 of Right Fork of Upper Cane	43	0.006
SUBTOTAL	3,195	0.569
Commissary Branch	2,667	0.509
RUT1 of Commissary Branch	21	0.003
RUT2 of Commissary Branch	28	0.004
LUT1 of Commissary Branch	38	0.005
SUBTOTAL	2,754	0.521
TOTAL CREDIT	5,949	1.090
NET GAIN	5,902	1.086

<u>Monitoring & Success Standards</u>

Channel stability, stream functions, biotic assessments, and vegetation survival will be visually monitored with photographs yearly as part of this mitigation project. Monitoring and success will be measured on each mitigation reach that involves stream restoration or enhancement work. Post-mitigation monitoring will be conducted for a minimum of five years following the completion of construction to document project success.

Biotic standards are contingent upon water quality parameters remaining within recommended ranges for freshwater organisms. Biotic standards will be monitored yearly. Each of the components described below (Table ES 1.3) will be monitored at the mitigation reaches.

Table ES 1.3
Success Criteria and Monitoring Actions

Type/Category	Criteria	Year 1	Year 2	Year 3	Year 4	Final Value (after 5 years)
Geomorphology	BEHI (Max)	High (Below 35)		Moderate (Below 30)		Moderate (Below 25)
	Sediment Production From Banks (bankpins or crosssections)	Report annual sediment production from banks	Report annual sediment production from banks	Report annual sediment production from banks	Report annual sediment production from banks	Mean sediment production from banks less than 0.5 feet/year over years 3-5
	Stable banks and channel (photos)*	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually

Type/Category	Criteria	Year 1	Year 2	Year 3	Year 4	Final Value (after 5 years)
Hydrology	Crest gage or observation	Report greater than bankfull flows	Report greater than bankfull flows	Report greater than bankfull flows	Report greater than bankfull flows	Greater than bankfull flows reached active floodplain stage during monitoring period
Vegetation	Min % Trees Native	50%	50%	50%	60%	75%
	Max % Trees Non-native	50%	50%	50%	40%	25%
	Max.% Trees Invasive	40%	40%	25%	25%	10%
	Max % Invasive plants (herbaceous or woody)	40%	40%	25%	25%	25%
	Min. Native Stem Density per acre	150	150	150	300	300
	Maximum Percent any one tree Species	50%	50%	50%	35%	25%
	Species List (Scientific & Common Name, Wetland Status Indicator, Native vs. Non-Native vs. Invasive)	Yes	Yes	Yes	Yes	Yes
Habitat	RBP	Report RBP score		Report RBP score		Mean RBP score "excellent" by year 5**
Biotic*	USEPA RBP (benthics)	Sample year 1		Sample year 3		Sample year 5 *Equivalent or higher metrics and values than a compared reach that has not been restored*

*RBP biotic metric will not be used to determine project success/failure, but goals have been set for year 5

**Minimum score to qualify as "Excellent" varies by bioregion

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1.0 INTRODUCTION AND BACKGROUND

1.1 Report Overview

This report is organized as follows:

- Section 1 describes the proposed restoration and enhancement project, goals and objectives for stream restoration and enhancement, and the approach to determine credits for the in-lieu fee program.
- Section 2 provides a review of the background science and methodologies applied by Michael Baker Jr., Inc., (Baker) in the practice of natural channel design. In addition, it provides the regulatory background for the proposed mitigation approach, including a method created in Kentucky to calculate mitigation credits.
- Section 3 provides watershed-level information on the proposed restoration and enhancement streams, including geology and soils, land use, habitat, and climate.
- Section 4 provides reach-level assessment information on the proposed restoration and enhancement streams. It describes their hydrologic and hydraulic, geomorphic, biotic, and water quality functions.
- Sections 5 through 14 include the restoration and enhancement plans for the selected areas, which include selection and application of design criteria. These sections also cover site monitoring, evaluation procedures for the post-implementation period, success standards, contingencies, long-term and adaptive management plans, and financial assurances.

1.2 Project Description and Location

Kentucky Department of Fish & Wildlife Resources (KY Fish & Wildlife) is in the process of obtaining all necessary state and federal permits for the proposed stream restoration and enhancement project, which includes portions of the Right Fork of Upper Cane Creek and two of its tributaries (3,695 linear feet) and Commissary Branch and three of its tributaries (2,821 linear feet). KY Fish & Wildlife Resources has already performed Biological Assessments for the Indiana bat, the Virginia big-eared bat, Gray bat, and White haired goldenrod and obtained a letter of concurrence from the U.S. Department of the Interior, Fish and Wildlife Service (FWS) that states the proposed project will have no effect on these protected species (Appendix A). Similarly, Kentucky's State Historic Preservation Office (SHPO) has provided a letter of concurrence that states no Historic Properties will be affected by the proposed project (Appendix B).

The project area is located approximately 5.5 miles north of Bowen in Menifee County, Kentucky (Figure 1.1) and borders the Daniel Boone National Forest. The project includes the restoration and enhancement of approximately 6,083 linear feet of the Right Fork of Upper Cane Creek and Commissary Branch, and their associated tributaries. The Right Fork of Upper Cane Creek flows into Upper Cane Creek located within the Red River basin of the Kentucky River (Figure 1.2). Commissary Branch flows into Right Fork of Upper Cane Creek at the most downstream end of the project area (Figure 1.2).

As part of the stream restoration and enhancement project, there will be one permanent stream crossing on an unnamed tributary of the Right Fork of Upper Cane Creek (RUT1 of Right Fork of Upper Cane Creek) in order to relocate an existing county road out of the stream channel and onto the hillside. Under Section 404 of the Federal Water Pollution Control Amendments of 1972, commonly referred to as the Clean Water Act (CWA), the USACE regulates the discharge of dredge and fill material into the "waters of the United States (U.S.)."

Therefore, KY Fish & Wildlife has requested that Baker prepare this Compensatory Mitigation and Restoration Plan for the proposed restoration, enhancement, and impact activities in jurisdictional waters at the proposed project area in accordance with the *Compensatory Mitigation for losses of Aquatic Resources; Final Rule* (EPA & USACE; 2008), hereafter referred to as the Mitigation Rule. This Mitigation Plan, also prepared in accordance to the Kentucky Fish & Wildlife In-Lieu Fee Agreement, includes final stream restoration and enhancement plan sheets (Appendix J).

1.3 Goals and Objectives

The objective of this Final Mitigation Plan is to provide a functional and structural lift at the proposed restoration and enhancement site by:

- Meeting guidelines provided in the Mitigation Rule (EPA & USACE; 2008);
- Providing Ecological Integrity Units as prescribed in the EKSAP protocol;
- Restoring geomorphically stable conditions, such that the correct stream type is in the appropriate valley type;
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1.4 Mitigation Credits

1.4.1 Eastern Kentucky Stream Assessment Protocol

KY Fish & Wildlife applied the Eastern Kentucky Stream Assessment Protocol at each of the restoration, enhancement, and impact sites located within the project area. The Eastern Kentucky Stream Assessment Protocol provides an estimate of the ecological integrity of a headwater stream ecosystem relative to reference stream conditions in the same region. The output of the model ranges from 0 – 1, and is calibrated such that a score of 1.0 is given for stream conditions indicative of least disturbed or reference streams in the region.

After compensating for the permanent ephemeral stream crossing, results from the Eastern Kentucky Stream Assessment Protocol demonstrate that the restoration and enhancement efforts throughout the Right Fork of Upper Cane and Commissary Branch watersheds will provide a functional lift of 1,297 EIUs (Table 1.1) (Appendix C).

Table 1.1
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Reach	Pre-existing Conditions			Predicted Conditions			Functional Lift
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1.4.2 Linear Feet

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1.5 Site Selection

1.5.1 Right Fork of Upper Cane Creek & Commissary Branch

The headwaters of the Upper Cane Creek watershed were selected by KY Fish & Wildlife as possible mitigation sites for stream restoration and enhancement for a number of reasons. Firstly, with the growing number of headwater impacts in the Eastern Kentucky region, there is a demand for mitigation in headwater streams to offset similar impacts. Selecting mitigation sites within the same physiographic region and stream type as the impacts will result in a greater likelihood of showing functional off-set.

Secondly, the practicability to obtain conservation easements or deed restrictions was available at the Upper Cane Creek project sites. Each of the project area landowners (Section 7.0) were willing to sign a site protection document to ensure that the proposed stream restoration and enhancement areas would be protected after mitigation measures were applied. The ability to obtain site protection documents is a driving factor in the selection of possible mitigation sites.

Finally, the Upper Cane Creek headwaters were unstable and in need of in-stream habitat enhancements. The stream has been channelized from an existing county road, which parallels and runs through several reaches of the Right Fork of Upper Cane Creek. Along Commissary Branch, there is a paralleling ATV road and abandoned gas lines, also causing the stream to be unstable with poor habitat and bedform diversity. These impacts have caused bank erosion and reduced riparian buffer widths. Thus, based on the selection criteria described above, the Right Fork of Upper Cane Creek and Commissary Branch appeared to be ideal candidates for stream restoration and enhancement for mitigation purposes.

2.0 REGULATORY METHODS

This section provides background materials on headwater streams and natural channel design techniques, along with describing the assessment methods used to evaluate the mitigation channels.

2.1 Jurisdictional Waters of the U.S.

The USACE issued a Regulatory Guidance Letter (RGL 08-02), which discusses approved and preliminary jurisdictional determinations (JDs) as tools used by the USACE to help implement Section 404 of the Clean Water Act (CWA) and Section 9 and 10 of the Rivers and Harbors Act of 1899 (RHA). The guidance explains the difference between the two types of JDs and appropriate scenarios to use either.

2.1.1 Approved JDs

Approved JDs identifies the limits of those waters on the project site determined to be jurisdictional under the CWA/RHA. The USACE will provide an approved JD to any landowner, permit applicant, or other "affected party" when requested. An approved JD is an official determination on the extent of any jurisdictional resources on the project site by the USACE and applies for 5 years.

2.1.2 Preliminary JDs

Preliminary JDs are "non-binding" documentation of resources which are possibly waters of the United States or wetlands. Preliminary JDs may be used by landowners or permit applicants for planning purposes to determine possible impacts and compensatory mitigation requirements. Permits issued on the basis of preliminary JDs treat all waters and wetlands as if they are jurisdictional waters of the U.S. In such cases, the USACE makes no legally binding determination regarding CWA/RHA jurisdiction.

For this mitigation plan, a preliminary JD form was completed and is included in Appendix D of this report.

2.2 Mitigation Methodology

2.2.1 Regulatory History

The USACE issued a Regulatory Guidance Letter (RGL 02-2), which discusses stream mitigation replacement. This protocol suggests a 1:1 linear foot replacement ratio of stream mitigation for all stream related impacts. KY Fish & Wildlife has complied with the minimal guidelines of RGL 02-2, providing more than a 1:1 linear foot replacement by restoring streams on-site and by creating channels on-site; in order to comply with the no net loss policy.

In the spring of 2003, the Louisville District published their Aquatic Resources News Regulatory Letter, which included publication of the *Stream Assessment Protocol for Headwater Streams in the Eastern Kentucky Coalfield Region* (Sparks et al; 2003b). This protocol was designed to be used in the Eastern Kentucky coalfield region to assign credits and debits to project sites for purposes of mitigation.

On April 10, 2008, the USACE and EPA issued regulations governing compensatory mitigation for activities authorized by permits issued by the USACE, entitled "Compensatory Mitigation for Losses of Aquatic Resources." The Federal Register, Volume 73, No. 70 is commonly known as the Mitigation Rule. The primary goal of the Mitigation Rule was to set a level playing field for mitigation banks, in-lieu fee programs, and permittees to the maximum extent practicable. Other goals of the Mitigation Rule included setting ecologically-driven performance standards that are equivalent, effective standards using the best available science. The Mitigation Rule states that compliance of permits will be more regulated having increased visits, established enforceable success criteria, and prescribed monitoring reports. Although the mitigation sequence has been preserved to avoid, minimize, and compensate for unavoidable impacts and lost aquatic functions, the preference hierarchy for mitigation options has changed to the following:

- Mitigation Banks
- In-Lieu Fee Programs
- Permittee-Responsible mitigation using a Watershed Approach
- On-site and/or in-kind permittee-responsible mitigation
- Off-site and/or out-of-kind permittee-responsible mitigation

With the Mitigation Rule, benefits include greater predictability and transparency, improved mitigation planning and site selection, improved performance of mitigation projects, possible reduction in permitting time, more flexible mitigation options, increased public participation, and re-enforces the watershed approach. The Mitigation Rule outlined requirements of Mitigation Banks, In-Lieu Fee Programs, and Permittee-Responsible mitigation; while also providing time frames for Federal review.

2.2.2 Eastern Kentucky Stream Assessment Protocol (EKSAP)

The Eastern Kentucky Stream Assessment Protocol (EKSAP) was devised by interagency cooperation among the U.S. Army Corps of Engineers (COE), the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), the Kentucky Division of Water (KDOW), and the Kentucky Department of Fish and Wildlife Resources (KDFWR). The protocol combines the EPA's Rapid Bioassessment Protocol (RBP) with macroinvertebrate population metrics to assess ecological integrity and fulfill requirements of Section 404 of the Clean Water Act in determining impacts and possible mitigation.

2.2.2.1 Stream Function

The Eastern Kentucky Stream Assessment Protocol (EKSAP) was developed to assess the ecological integrity of headwater streams of the Eastern Kentucky Coalfield Region. EKSAP utilizes macroinvertebrate surveys, to measure biotic integrity, along with the EPA's Rapid Bioassessment Protocol (RBP) and the conductivity of the water within the stream, to assess abiotic or habitat integrity. The evaluations are combined to create an ecological integrity index (EII) of a headwater stream.

<u>Biotic Integrity</u> focuses on five (5) selected metrics of collected macroinvertebrate populations: Taxa richness, EPT richness, mHBI, %Clingers, % Ephemeroptera, and %Chironomidae+Oligochaeta for calculation of the biotic integrity of the stream.

<u>Abiotic Integrity</u>: Focuses on the available habitat quality, which is based on the EPA RBP scoring system and the conductivity of the water, as direct correlations have been seen with these parameters and stream function. The parameters that have shown to have the highest correlation are Riparian width, Canopy cover, and Embeddedness.

2.2.2.2 Mitigation Requirements

The evaluations are combined to create an ecological integrity index (EII) of a headwater stream:

Ecological Integrity Index = Macroinvertebrate Bioassessment Index + Conductivity + Total Habitat Score

---

3

All three parameters (MBI, Conductivity, and Habitat Score) are equally rated and an average of the available evaluations is calculated to determine the EII.

2.2.2.3 Determination of Mitigation Credits

EII are multiplied by the length of stream proposed to be impacted or mitigated, the resulting score are the Ecological Integrity Units (EIUs). The proposed parameters of the mitigation areas are then applied to the EIUs in order to calculate net gains per reach and then toward the overall project's net gain or loss of EIUs.

2.2.2.4 Summary of the EKSAP Approach

This approach is designed to supply an accurate crediting/debiting value rapidly for the purposes of obtaining the necessary permits in an efficient, yet accurate manner. The obtained values can be applied to the no net loss of function in the mitigation plan. This protocol is based on the appropriate techniques in sampling, analysis, and application.

2.3 Application of Fluvial Processes to Stream Restoration

A stream and its floodplain (referred to here as the riparian area) comprise a dynamic environment in which the floodplain, wetland areas, channel, and bedform evolve through natural processes. Weather and hydraulic processes erode, transport, sort, and deposit alluvial materials throughout the riparian system. The size and flow of a stream are directly related to its watershed area. Other factors that affect channel size and stream flow are geology, land use, soil types, topography, and climate. The morphology, or size and shape, of the channel reflects all of these factors (Leopold et al., 1964; Knighton, 1998). Under stable conditions, the result is a dynamic equilibrium in which the stream maintains its dimension, pattern, and profile over time. Changes in watershed land use, including increases in imperviousness and removal of riparian vegetation. A new equilibrium may eventually result, but not before large adjustments in channel form can occur, such as extreme bank erosion or incision (Lane, 1955; Schumm, 1960). By understanding and applying the processes of fluvial form and function to stream restoration projects, a self-sustaining riparian system that maximizes ecosystem function and potential can be designed and constructed.

The following sections describe the processes that Baker uses when developing stream restoration projects using natural channel design concepts.

2.3.1 Considerations for Ephemeral Channels

In mountain environments, ephemeral channels are found on steep slopes near the boundaries of watersheds, and route surface runoff to down-gradient intermittent and perennial channels. Often, these channels are poorly defined and do not exhibit fluvial features such as bed material sorting and complex bed profiles. Because these channels only carry water infrequently and for short time periods, they do not support aquatic populations and biologically function as terrestrial habitat.

The principles of fluvial processes and channel-forming discharge are most applicable to intermittent and perennial stream channels. For high-gradient ephemeral stream channels of the Appalachian Mountains, research has shown little correlation between channel size, watershed area, and a given-return period flow. Instead, ephemeral channel size and dimension are primarily controlled by valley topography, bedrock knick-points, and past disturbance (Adams, 2002). For this reason, the sections below that discuss the design of channel dimension, pattern, and profile for intermittent and perennial channels do not apply to the design of ephemeral channels.

Bakers design approach for ephemeral channel restoration is to convey ephemeral flows in a way that does not cause excess degradation or erosion of the hillslope. Channels are sized to accommodate the 2 to 5 year return period 24-hour storm event. Grade control structures are included where appropriate to protect the channels from incision, excess erosion, and gullying. Emphasis is also placed on restoring riparian vegetation adjacent to the channels, to provide bank and channel stability and provide a source of organic debris to intermittent and perennial receiving waters downstream.

2.3.2 Channel-Forming Discharge

The channel-forming discharge, also referred to as bankfull discharge, effective discharge, or dominant discharge, creates a natural and predictable channel size and shape (Leopold et al., 1964; Leopold, 1994). Channel-forming discharge theory proposes that there is a unique flow that over a long period of time would yield the same channel morphology that is shaped by the natural sequence of flows. At this discharge, equilibrium is most closely approached, and the tendency to change is least (Inglis, 1947). Uses of the channel-forming discharge include channel stability assessment, river management using hydraulic geometry relationships, and natural channel design (Soar and Thorne, 2001).

Proper determination of bankfull stage in the field is vital to stream classification and the natural channel design process. The bankfull discharge is the point at which flooding occurs on the floodplain (Leopold, 1994). This flood stage may or may not be the top of the streambank. On average, bankfull discharge occurs every 1.5 years (Leopold, 1994; Harman et al., 1999; McCandless, 2003). If the stream has incised due to changes in the watershed or streamside vegetation, the bankfull stage may be a small, depositional bench or scour line on the streambank (Harman et al., 1999); in this case, the top of the bank, which was formerly the floodplain, is called a terrace. A stream with terraces at the top of its banks is incised.

2.3.3 Bedform Diversity and Channel Substrate

The profile of a stream bed and its bed materials is largely dependent on valley slope and geology. In simple terms, steep, straight streams are found in steep, colluvial valleys, while flat, meandering streams are found in flat, alluvial valleys. Colluvial valleys have slopes between 2% and 4%, while alluvial channels have slopes less than 2%. A colluvial valley forms through hillslope processes. Sediment supply in colluvial valleys is controlled by hillslope erosion and mass wasting; i.e., the sediments in the stream bed originate from the hillslopes. Sediments reaching the channel in a colluvial valley are typically poorly sorted mixtures of fine and coarse-grained materials, ranging in size from sand to boulders. In contrast, an alluvial valley forms through stream and floodplain processes. Sediments in alluvial valleys include some coarse gravel and cobble transported from steeper upland areas but are predominantly fine-grained particles, such as gravel and sand. Grain size generally decreases with valley slope (Leopold et al., 1964).

2.3.3.1 Step/Pool Streams

A step/pool bed profile is characteristic of steep streams formed within colluvial valleys. Steep mountain streams demonstrate step/pool morphology as a result of episodic sediment transport mechanisms. Because of the high energy associated with the steep channel slope, the substrate in step/pool streams contains significantly larger particles than streams in flatter alluvial valleys. Steps form from accumulations of boulders and cobbles that span the channel, resulting in a backwater pool upstream and a plunge pool downstream. Smaller particles collect in the interstices of steps, creating stable, interlocking structures (Knighton, 1998).

In contrast to meandering streams that dissipate energy through meander bends, step/pool streams dissipate energy through drops and turbulence. Step/pool streams have relatively low sinuosity. Pattern variations are commonly the result of debris jams, topographic features, and bedrock outcrops.

2.3.3.2 Gravel Bed Streams

Meandering gravel bed streams in alluvial valleys have sequences of riffles and pools that maintain channel slope and bed stability. The riffle is a bed feature composed of gravel or larger-size particles. During low-flow periods, the water depth at a riffle is relatively shallow, and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, providing oxygen to the stream. Riffles control the stream bed elevation and are usually found entering and exiting meander bends. The inside of the meander bend is a depositional feature called a point bar, which also helps maintain channel form (Knighton, 1998). Pools are typically located on the outside bends of meanders, between riffles. Pools have a flat slope and are much deeper than the average depth of the channel. At low flows, pools are depositional features, and riffles are scour features.

At high flows, the water surface becomes more uniform; i.e., the water surface slope at the riffles decreases, and the water surface slope at the pools increases. The increase in pool slope coupled with the greater water depth at the pools causes an increase in shear stress at the bed elevation. The opposite is true at riffles. With a relative increase in shear stress, pools scour. The relative decrease in shear stress at riffles causes bed material deposits at these features during the falling limb of the hydrograph.

2.3.4 Stream Classification

The Rosgen Stream Classification System categorizes essentially all types of channels based on measured morphological features (Rosgen, 1994, 1996). The system, illustrated in Figure 2.1, presents several stream types, based on a hierarchical system. The first level of classification distinguishes between single and multiple-thread channels. Streams are then separated according to degrees of entrenchment, width/depth ratio, and sinuosity. Slope range and channel materials are also evaluated to subdivide the streams. Stream types are further described according to average riparian vegetation, organic debris, blockages, flow regimes, stream size, depositional features, and meander pattern.

Bankfull stage is the basis for measuring the width/depth and entrenchment ratios, two of the most important delineative criteria; therefore, it is critical to correctly identify bankfull stage when classifying streams and designing stream restoration measures. A detailed discussion of bankfull stage is provided in Section 2.4.2.

2.3.5 Stream Stability

A naturally stable stream must be able to transport the sediment load supplied by its watershed while maintaining dimension, pattern, and profile over time so that it does not degrade or aggrade (Rosgen, 1994). Stable streams migrate across and through landscapes slowly, over long periods of time, while maintaining their form and function. Instability occurs when scouring causes the channel to incise (degrade) or when excessive deposition causes the channel bed to rise (aggrade). A generalized relationship of stream stability proposed by Lane (1955) is shown as a schematic drawing in Figure 2.2. The drawing shows that the product of sediment load and sediment size is proportional to the product of stream slope and discharge or stream power. A change in any one of these variables causes a rapid physical adjustment in the stream channel.

2.3.6 Channel Evolution

A common sequence of physical adjustments has been observed in many streams following disturbance. This adjustment process is often referred to as channel evolution. Disturbance can result from channelization, increase in runoff due to build-out in the watershed, removal of streamside vegetation, and other changes that negatively affect stream stability. All of these disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream. The Simon (1989) Channel Evolution Model characterizes evolution in six steps:

I. sinuous, pre-modified,
II. channelized,
III. degradation,
IV. degradation and widening,
V. aggradation and widening, and
VI. quasi-equilibrium.

Figure 2.3 illustrates the six steps of the Simon Channel Evolution Model.

The channel evolution process is initiated once a stable, well-vegetated stream that interacts frequently with its floodplain is disturbed. Disturbance commonly causes increased in-stream power that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the banks, and when critical bank heights are exceeded, the banks begin to fail, and mass wasting of soil and rock leads to channel widening. Incision and widening continue moving upstream in the form of a head-cut. Eventually, the mass wasting slows, and the stream begins to aggrade. A new, low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream with dimension, pattern, and profile similar to those of undisturbed channels forms in the deposited alluvium. The new channel is at a lower elevation than its original form, with a new floodplain constructed of alluvial material (Federal Interagency Stream Restoration Working Group, FISRWG, 1998).

2.3.7 Priority Levels of Restoring Incised Rivers

Though incised streams can occur naturally in certain landforms, they are often the product of disturbance. Characteristics of incised streams include high, steep streambanks; poor or absent in-stream or riparian habitat; increased erosion and sedimentation; and low sinuosity for meandering streams. Complete restoration, in which the incised channel's grade is raised so that an abandoned floodplain terrace is reclaimed, is the ideal, overriding objective of stream restoration. Such an objective may be impractical, however, when homes, roadways, utilities, or other structures have encroached upon the abandoned floodplain. A priority system for the restoration of incised streams, developed and used by Rosgen (1997), considers a range of options to provide the best level of stream restoration possible for a given setting. Figure 2.4 illustrates various restoration/stabilization options for incised channels within the framework of the Rosgen priority system. Generally:

- Priority 1 – Re-establishes the channel on a previous floodplain (i.e., raises channel elevation); restores a new channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel. This option requires that the upstream start point of the project not be incised.
- Priority 2 – Establishes a new floodplain at the existing bankfull elevation (i.e., excavates a new floodplain); restores channel to achieve the dimension, pattern, and profile characteristic of a stable stream for the particular valley type; and fills or isolates existing incised channel.
- Priority 3 – Converts a straight channel to a different stream type while leaving the existing channel in place, by excavating bankfull benches at the existing bankfull elevation. Effectively, the valley for the stream is made more bowl-shaped. This approach uses in-stream structures to dissipate energy through a step/pool channel type.
- Priority 4 – Stabilizes the channel in place, using in-stream structures and bioengineering to decrease stream bed and streambank erosion. This approach is typically used in highly-constrained environments.

2.4 Natural Channel Design Overview

Restoration design of degraded stream reaches first involves accurately diagnosing their current condition. Understanding valley type, stream type, channel stability, sources of impairment, bedform diversity, and potential for restoration is essential to developing adequate restoration measures (Rosgen, 1996). This combination of assessment and design is often referred to as natural channel design.

The first step in a stream restoration design is to assess the reach, its valley, and its watershed in order to understand the relationship between the stream and its drainage basin and to evaluate the causes of stream impairment. Bankfull discharge is estimated for the watershed. After sources of stream impairment are identified and channel geometry is assessed, a plan for restoration can be formulated.

Design commences at the completion of the assessment stage. A series of iterative calculations are performed using data from reference reaches, pertinent literature, and evaluation of past projects to develop an appropriate, stable cross-section, profile, and plan form dimensions for the design reach. A thorough discussion of design parameter selection is provided in Section 2.10. The alignment should avoid an entirely symmetrical layout to mimic natural variability, create a diversity of aquatic habitats, and improve aesthetics.

Once a dimension, pattern, and profile have been developed for the project reach, the design is tested to ensure that the new channel will not aggrade or degrade. A discussion of sediment transport methodology is provided in Section 2.11.

After the sediment transport assessment, additional structural elements are added to the design to provide grade control, protect streambanks, and enhance habitat. Section 2.16 describes these in-stream structures in detail.

Once the design is finalized, detailed drawings are prepared to show dimension, pattern, profile, and location of additional structures. These drawings are used in the construction of the project.

Following the implementation of the design, a monitoring plan is established to:

- Ensure that stabilization structures are functioning properly;
- Monitor channel response in dimension, pattern and profile, channel stability (aggradation/degradation), particle size distribution of channel materials, and sediment transport and streambank erosion rates;
- Determine biological response (food chains, standing crop, species diversity, etc.); and
- Determine the extent to which the restoration objectives have been met.

2.5 Geomorphic Characterization Methodology

Geomorphic characterization of stream features includes bankfull identification, bed material characterization and analysis, and stream classification.

2.5.1 Bankfull Identification

Field techniques used for bankfull identification are as follows:

- Identify the most consistent bankfull indicators along the reach that were obviously formed by the stream, such as a point bar or lateral bar. Bankfull is usually the back of this feature, unless sediment supply is high; in that case, the bar may flatten, and bankfull will be the front of the feature at the break in slope. The indicator is rarely the top of the bank or lowest scour mark.
- Measure the difference in height between the water surface and the bankfull indicator; for example, the indicator may be 2.2 feet above water surface. Bankfull stage corresponds to a flow depth. It should not vary by more than a few tenths of a foot throughout the reach, unless a tributary enters the reach and increases the size of the watershed.
- Look for bankfull indicators at a stable riffle. If a bankfull indicator is not present at this riffle, use the height measured in the previous step to establish the indicator; for example, measure 2.2 feet above water surface, and place a flag in both the right and left banks.
- Measure the distance from the left bank to the right bank between the indicators. Calculate the cross-sectional area.
- Obtain the appropriate regional curve for the project area and determine the cross-sectional area associated with the drainage area of the reach.
- Compare the measured cross-sectional area to that of the regional curve. If the measured cross-sectional area is not a close fit, look for other bankfull indicators, and test them. If there are no other indicators, look for reasons to explain the difference between the two cross-sectional areas; for example, if the cross-sectional area of the stable riffle is lower than the regional curve area, look for upstream impoundments, wetlands, or a mature forested watershed. If the cross-

sectional area is higher than the regional curve area, look for stormwater drains, parking lots, or signs of channelization.

It is important to perform the bankfull verification at a stable riffle, using indicators from depositional features. The cross-sectional area will change with decreasing stability. In some streams, bankfull indicators will not be present due to incision or maintenance. In such cases, it is important to verify bankfull through other means, such as a gage station survey or reference bankfull information that is specific to the geographic location. The gage information can be used to verify the applicability of the regional curve to a localized area.

2.5.2 Bed Material Characterization

For gravel bed systems, bed material characterizations were performed using a modified Wolman procedure (Wolman, 1954; Rosgen, 1996). A 100-count pebble count is performed in transects across the stream bed, with the number of riffle and pool transects proportional to the percentage of riffles and pools within the longitudinal distance of a given stream type. As stream type changes, a separate pebble count is performed. The median particle size of the modified Wolman procedure is known as the D50. The D50 describes the bed material classification for that reach. The Rosgen bed material classification is shown in Figure 2.1 and ranges from a classification of 1, for a channel D50 of bedrock, to a classification of 6, for a channel D50 in the silt/clay particle size range.

The modified Wolman pebble count is not appropriate for sand bed streams. When working in sand bed systems, a bulk sampling procedure is used to characterize the bed material. Cores (2” - 3” deep) are sampled from the bed along the entire reach. These cores are taken to a lab and dry-sieved to obtain a sediment size distribution. This information is used to classify the stream and to complete the sediment transport analysis.

2.5.3 Stream Classification

Cross-sections are surveyed along riffles for the purpose of stream classification. Values for entrenchment ratio and width/depth ratio, along with sinuosity and slope, are used to classify the stream. The entrenchment ratio (ER) is calculated by dividing the flood-prone width (width measured at twice the maximum bankfull depth) by the bankfull width. The width/depth ratio (w/d ratio) is calculated by dividing bankfull width by mean bankfull depth. Figure 2.5 shows examples of the channel dimension measurements used in the Rosgen Stream Classification System.

Finally, the numbers that coincide with each bed material classification are used to further classify the stream type; for example, a Rosgen E3 stream type is a narrow and deep, cobble-dominated channel, with access to a floodplain that is greater than two times its bankfull width.

2.6 Channel Stability Assessment Methodology

Evaluation methods from the stream stability assessment methodology developed by Rosgen (2001b) were used for the project. The Rosgen method is a field assessment of the following stream channel characteristics:

- Stream channel condition,
- Vertical stability,
- Lateral stability,
- Channel pattern,
- River profile and bed features,
- Channel dimension relations, and
- Channel evolution.

This field exercise is followed by the evaluation of various channel dimension relationships.

Evaluation of the above characteristics and relationships leads to a determination of a channel's current state, potential for restoration, and appropriate restoration activities. A description of each characteristic is provided in the following sections.

2.6.1 Stream Channel Conditions

Stream channel conditions observed during initial field inspections (stream walk) included the follow characteristics:

- Riparian vegetation – concentration, composition, and rooting density;
- Sediment depositional patterns – mid-channel bars and other depositional features that indicate aggradation and can lead to negative geomorphic channel adjustments;
- Debris occurrence – presence or absence of woody debris;
- Meander patterns – general observations with regard to the type of adjustments a stream will make to reach equilibrium; and
- Altered states due to direct disturbance – channelization, berm construction, and floodplain alterations, etc.

These qualitative observations are useful in the assessment of channel stability. They provide a consistent method of documenting stream conditions that allows comparison across different sets of conditions. The observations also help explain the quantitative measurements described below.

2.6.2 Vertical Stability – Degradation/Aggradation

The bank height and entrenchment ratios are measured in the field to assess vertical stability. The bank height ratio is measured as the ratio of the lowest bank height divided by a maximum bankfull depth. Table 2.1 shows the relationship between bank height ratio (BHR) and vertical stability developed by Rosgen (2001).

Table 2.1
Conversion of Bank Height Ratio (Degree of Incision) to Adjective Rankings of Stability (Rosgen, 2001b)

Adjective Stability Rating	Bank Height Ratio
Stable (low risk of degradation)	1.0 – 1.05
Moderately unstable	1.06 – 1.3
Unstable (high risk of degradation)	1.3 – 1.5
Highly unstable	> 1.5

The entrenchment ratio is measured as the width of the floodplain at twice the maximum bankfull depth. If the entrenchment ratio is less than 1.4 (+/- 0.2), the stream is considered entrenched (Rosgen, 1996).

2.6.3 Lateral Stability

The degree of lateral containment (confinement) and potential lateral erosion are assessed in the field by measuring the meander width ratio (MWR) and the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001a). The MWR is the meander belt width divided by the bankfull channel width. This measurement provides insight into lateral channel adjustment processes, depending on stream type and degree of confinement. For example, an MWR of 3.0 often corresponds with a sinuosity of 1.2, which is the minimum value for a stream to be classified as meandering. If the MWR is less than 3.0, lateral adjustment is probable. BEHI ratings along with near bank shear stress estimates can be compared to data from monitored sites and used to estimate the annual lateral streambank erosion rate.

2.6.3.1 Bank Erosion Hazard Index (BEHI)

The numerical score on which the BEHI rating is based depends on the following:

- Bank Angle. The angle measured from the toe of the streambank slope against the dominant slope of the lower bank. If the bank slopes toward the hill slope it is less than 90 degrees; vertical banks have 90-degree slopes.
- Bank Height Ratio. The height of streambank as measured from the thalweg, divided by the bankfull height.
- Ratio of Root Depth to Bank Height. Measures the depth to which the bank is stabilized by root mass
- Root Density. Measures the percentage of the streambank that is stabilized by root mass.
- Surface Protection. Measures the percentage of the streambank that is protected by surface vegetation, rocks, or other material that serves to armor the bank.

Once each of the five parameters is observed (bank angle, bank height ratio, rooting depth, root density, and surface protection) and assigned a value, a scoring table is used to determine the bank erosion potential for each parameter (scoring is based on original research by Rosgen and extrapolated from graphs into tabular form). Once each parameter has been assigned a score, the parameter scores are added together for a total score. The total score is then adjusted dependent upon the bank material composition. Final scores are assigned to the following categories: Very Low, Low, Moderate, High, Very High, and Extreme.

2.6.3.2 Near Bank Stress

Near Bank Stress (NBS) is a value extrapolated from the velocity gradients and shear stress in the near bank region. If the cross-sectional base flow channel is split into thirds, the near bank region is the closest one-third to the study bank. Studies measuring in-stream velocities show the strongest velocities occur within the thalweg region. Conversely, the weakest velocities are seen in the areas that are shallow and have a decreased bank angle or channel slope. This explains, in part, why deposition occurs on the point bar, and scour occurs against the apex of the meander bend where the thalweg is often located in close proximity to the toe of the streambank. This scour deepens the pool and may cause the channel to laterally migrate through bank erosion against the outside of the meander bend.

NBS values are can be assessed as Very Low, Low, Moderate, High, Very High, or Extreme (Table 2.2). Values are estimated based on the shape of the near bank region along with the direction of flow. Typically bar deposits have high or very high NBS values and pools have lower NBS values. NBS can be calculated through careful measurements of cross-sections and the development of bank profiles. Cross-sections should be performed on each study bank. First, the mean depth (dbkf = Abkf / Wbkf) is determined. Then, the bankfull width is divided into thirds (Wbkf / 3). Next, the maximum depth in the near bank region (dnb) is determined. Then, the maximum depth of the near bank region is divided by the mean depth (dnb/d). If the study bank is located along the outside of a meander bend, NBS can be determined by calculating the radius of curvature and dividing that by the bankfull width (Rc/Wbkf). If the study bank is located within a pool, two methods can be used. One involves dividing the slope of the pool by the average water surface slope (S_p/S) or by dividing the pool slope by the riffle slope immediately upstream of the pool (S_p/S_{rif}).

Table 2.2
Ratings for NBS for Various Cross-Sectional Values (Rosgen, 2001a)

NBS Rating	Rc/Wbkf	S_p/S	S_p/S_{rif}	dnd/d
Very Low	>3.0	<0.2	<0.4	<1.0
Low	2.21-3.0	0.2-0.4	0.41-0.6	1.0-1.5
Moderate	2.01-2.2	0.41-0.6	0.61-0.8	1.51-1.8

NBS Rating	Rc/Wbkf	S_p/S	S_p/S_{rif}	dnd/d
High	1.81-2.0	0.61-0.8	0.81-1.0	1.81-2.5
Very High	1.5-1.8	0.81-1.0	1.01-1.2	2.51-3.0
Extreme	<1.5	>1.0	>1.2	>3.0

2.6.4 Channel Pattern

Channel pattern is assessed in the field by measuring the stream's plan features, including radius of curvature, meander wavelength, meander belt width, stream length, and valley length. Results are used to compute the meander width ratio (described above), ratio of radius of curvature to bankfull width, sinuosity, and meander wavelength ratio (meander wavelength divided by bankfull width). These dimensionless ratios are compared to reference reach data for the same valley and stream type to assess whether channel pattern has been impacted.

2.6.5 River Profile and Bed Features

A longitudinal profile is created by measuring and plotting elevations of the channel bed, water surface, bankfull, and low bank height. Profile points are surveyed at prescribed intervals and at significant breaks in slope, such as the head of a riffle or pool. This profile can be used to assess changes in river slope compared to valley slope, which affect sediment transport, stream competence, and the balance of energy; for example, the removal of large woody debris may increase the step/pool spacing and result in excess energy and subsequent channel degradation. Facet (e.g., riffle, run, pool) slopes of each individual feature are important for stability assessment and design.

2.6.6 Channel Dimension Relations

The bankfull width/depth ratio provides an indication of departure from reference reach conditions and relates to channel instability. A greater width/depth ratio compared to reference conditions may indicate accelerated streambank erosion, excessive sediment deposition, stream flow changes, and alteration of channel shape (e.g., from channelization). A smaller width/depth ratio compared to reference conditions may indicate channel incision and downcutting. Both increases and decreases in width/depth ratio can indicate evolutionary shifts in stream type (i.e., transition of one stream type to another). Table 2.3 shows the relationship between the degree of width/depth ratio increase and channel stability developed by Rosgen (2001b).

Table 2.3
Conversion of Width/Depth Ratios to Adjective Ranking of Stability from Stability Conditions (Rosgen, 2001b)

Stability Rating	Ratio of Project to Reference Width/depth
Very stable	1.0
Stable	1.0 – 1.2
Moderately unstable	1.21 – 1.4
Unstable	> 1.4

While an increase in width/depth ratio is associated with channel widening, a decrease in width/depth ratio is associated with channel incision; hence, for incised channels, the ratio of channel width/depth ratio to reference reach width/depth ratio will be less than 1.0. The reduction in width/depth ratio indicates excess shear stress and movement of the channel toward an unstable condition.

2.6.7 Channel Evolution

Simon's Channel Evolution Model (introduced in Section 2.4.6) relies on a qualitative, visual assessment of the existing stream channel characteristics, such as bank height, evidence of degradation/aggradation, presence of bank slumping, and direction of bed and bank movement. Establishing the evolutionary stage of the channel helps ascertain whether the system is moving towards greater stability or instability. The model also provides a better understanding of the cause and effect of channel change. This information, combined with Rosgen's (1994) priority levels of restoration, aids in determining the restoration potential of unstable reaches.

2.7 Hydrologic and Hydraulic Methodology

Watershed hydrology answers the question, "how much water, in the form of runoff, is produced by different rainfall events?" Quantitative hydrology provides a discharge and a corresponding return interval, e.g. the 100-year discharge. Channel hydraulics characterizes the way a given discharge will function in the channel and floodplain. Quantitative measures of channel hydraulics include, velocity, shear stress, flood depth, etc. A variety of models are used to describe hydrology and hydraulic functions. Some models are better suited for small, steep gradient watersheds and others work better in low gradient, larger watersheds. A description of the approaches used for this project is provided below.

2.7.1 High Gradient Ephemeral/Intermittent Streams

Discharges for the potential impact reaches were calculated using the NRCS Graphical Method developed by the Natural Resources Conservation Service (NRCS) formerly known as the Soil Conservation Service (SCS). The Graphical Method was developed for calculating peak discharges for small watersheds and is considered appropriate for estimating discharges where gaged flow data are unavailable.

A single cross-section approach was selected for evaluating the channel hydraulics. A cross-section was selected to represent a reach within each potential impact stream. The selected reach is representative of a segment where field evidence of fluvial processes was noted, e.g. the presence of a step-pool or riffle-pool sequence. Discharge rating (stage-discharge) and shear stress rating (stage-shear stress) curves were developed for the selected cross-sections using the computer program WinXSPRO, A Channel Cross-Section Analyzer, Version 3.0, developed by the U.S. Forest Service. WinXSPRO was developed for use in high gradient streams and uses a resistance equation approach.

Both the frequency (in years) of the discharge that resulted in a water depth to that of the bankfull indicator and that completely filled the channel was determined using the stage-discharge rating curve and discharge-frequency curve. Similarly, the shear stress rating curves were used to obtain bankfull shear stress. The bankfull shear stress was used to determine the particle size capable of being transported (Dcritical in mm) from the critical shear stress curve (Figure 2.6). The Dcritical was compared to the particle size distribution curve of the sampled stream bed material to evaluate the potential for significant bed material entrainment. The stream bed material was sampled using the pebble count technique.

Adams and Spotila (2005) found that headwater streams do not display clear relationships between channel morphology, substrate, and drainage area. This differs from larger watersheds where fluvial processes are more prominent. In these small, steep gradient watersheds, the channel is more strongly influenced by the surrounding hillslopes and local boundary conditions, such as bedrock.

Due to the variability in channel morphology evaluating the hydraulics of steep mountain streams is very complex. Most of the methods developed are still confined to the realm of research. The following discussion pertains to the complexities associated with this type of analysis.

2.7.1.1 Flow Resistance Estimation

There is a lack of accurate methods for predicting flow resistance in steep mountain streams (Thorne and Zevenbergen, 1985). Conventional methods focus on grain resistance neglecting the effects of form (Papanicolaou et al., 2004). The limitations of these methods are quite significant in streams where the vertical protrusion of the largest particles is relatively large and sometimes exceeds the bankfull depth of flow (Papanicolaou et. al., 2004). The following conventional methods were examined for use: Thorne & Zevenbergen (1985), Jarrett (1984), Nelson et al. (1991), Limerinos (1970), Manning (1889), and Cowan (1956). It was concluded that the channel reaches being examined are far outside the limits of these methods. Therefore, a modified Manning's roughness value was used to characterize the flow resistance based on Cowan's method. This yielded roughness values that were fairly consistent with Jarrett's Method (1984).

2.7.1.2 Critical Stress Estimation

Quantifying the critical stress of sediment particles in mountain streams poses an extra degree of difficulty. The incipient motion of sediment is affected by surface waves and the entrained air bubbles that are generated as the flow plunges to the protruding roughness elements (Papanicolaou et. al., 2004). These complex flow aspects were not considered in this analysis. Steady flow conditions were assumed to be valid for computing shear stress values. Competency was assessed by plotting grain diameter (mm) versus critical shear stress (lbs/sqft) on a graph developed by Leopold et al. (1964) and Rosgen and Silvey (2005) as adopted by the USEPA (2005). For this analysis, the Leopold curve was used because it represents data from streams with rounded bed material as opposed to irregular shaped glacial till. However, these relationships may not be representative of steep mountain streams, such as the potential impact reaches.

2.7.1.3 Energy Slope Estimation

The energy slope was estimated to be equal to the local bed slope for low flows. For high flows, the energy slope was assumed to be equal to the average bed slope.

2.7.1.4 Bankfull Stage Estimation

Field observed bankfull indicators were identified and survey as part of a cross-section taken at stable riffles and pools. The relevance of these indicators in the application in regards to small, steep mountain streams is still unknown. Some of the study reaches have extremely small drainage areas and likely did not have channels prior to European settlement and land clearing. When the forests were removed, peak runoff likely increased, creating rills and gullies. With reforestation, and the presence of bedrock and colluvium, the channels have stabilized. Since large storms may have created these channels, the return interval at the top of bank or bankfull is much higher than bankfull indicators in perennial streams that must transport the sediment that is delivered by the watershed.

2.8 Biotic Assessment Methodology

Physical habitat surveys allow investigators to document the relative quality and quantity of habitat available for both aquatic and terrestrial organisms. For instance, physical habitat has been correlated to the prediction of fish in a stream reach (Gorman and Karr 1978, Binns and Eiserman 1979, Schlosser 1982, Fausch et al. 1988, Lyons 1991). A wide variety of methodologies and procedures is available to sample physical habitat and stream conditions (Armantrout, 1982; Oswood and Barbar, 1982; Van Deventer and Platts 1983; Simonson et al., 1994).

Habitat and biological surveys of benthic macroinvertebrates followed US Environmental Protection Agency's (USEPA's) *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition* (Barbour et al., 1999) since it was one of the most recent sampling protocols available. The practical method is widely used, applicable to all wadeable streams and rivers, is recommended by many regulators (USEPA, 2000), and is a rapid and cost efficient protocol adapted by many other state agencies.

2.8.1 Stream Habitat

Habitat assessments for the project were developed using the USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition* (Barbour et al., 1999). The USEPA method allows for a visual-based habitat assessment that precludes the need for multiple biological evaluations. The assessment focuses on the following habitat features: in-stream habitat, channel morphology, bank structural features, and riparian vegetation. A total of ten parameters are rated as optimal, suboptimal, marginal, or poor based on criteria included in a Habitat Assessment Field Data Sheet.

There are studies documenting the relationships between habitat variables and the abundance of biota. The Rapid Bioassessment Protocols utilize these relationships to assess habitat as a surrogate for biotic function, and builds on protocols used by states since the 1980s (most directly from the Wisconsin Methods of Evaluating Stream, Riparian, and Biotic Conditions). The approach used in other countries, including Great Britain, is similar to this, visual-based approach (Barbour et al., 1999).

The USEPA method has two basic approaches, one for high-gradient streams and another for low-gradient streams. High gradient streams are prevalent in the project area. Substrates in these streams tend to be coarse particulates. In lower gradient streams, fine particulates are more common.

The USEPA method requires analysis of either 100 meters of stream length or 40 times the streams wetted width. Visual and biological assessments should not be separated in distance. Teams of two assessors are encouraged so that a consensus can be reached for each stream. The following parameters were evaluated for high-gradient streams:

- Epifaunal Substrate/Available Cover. Evaluates the relative quantity and variety of natural structures in the stream such as cobbles (riffles), large rocks, large woody debris (LWD), and undercut banks. Greater than 70% is rated as optimal, less than 20% is considered to be poor.
- Embeddedness. Describes the extent to which rocks and other material in the stream are covered or sunken into the silt, mud or sand of the stream bottom. Less than 25% embeddedness is considered to be optimal; greater than 75% is considered to be poor.
- Velocity/Depth Combinations. An optimal habitat would have areas of slow, deep water; fast, deep water; slow, shallow water; and fast, shallow water. Streams rated optimal have all four varieties, those rated as poor are dominated by one.
- Sediment Deposition. The presence of point bars or islands tends to indicate less stable streambank conditions and lower water quality. Less than 5% of the streambed covered with sediment is considered to be optimal, greater than 50% is considered to be poor.
- Channel Flow Status. Describes the degree to which the stream fills the available channel. Generally speaking, the higher the percentage of the stream channel that is filled by water, the higher the water quality; greater than 75% is considered optimal, less than 25% indicates poor conditions.
- Channel Alteration. Evaluates the stream for channelization or dredging versus a natural stream channel. An absence of channelization is considered to be optimal, greater than 80% altered is considered to be poor.
- Frequency of Riffles (or Bends). Measures the sequence of riffles by dividing the ratio between the riffles by the width of the stream. Ratios less than 7:1 are indicative of optimal conditions, ratios less than 25:1 indicate poor conditions.
- Bank Stability. Determines the percentage of assessed streambank that have been eroded. Less than 5% is considered optimal, over 60% is considered poor.
- Bank Vegetative Protection. Estimates the amount of protection that area vegetation affords in the near-stream portion of the riparian zone. If more than 90% of the streambank surface is covered by vegetation, the stream is rated as optimal, if less than 50% is covered, it is rated as poor.

- Riparian Vegetation Zone Width. Measures the width of the riparian zone. If over 60 feet, the riparian buffer is considered to be in optimal condition. If less than 20 feet, it is considered to be poor.

There was one stream in the project study area (Lukey Fork, a proposed mitigation stream) that qualifies as a low gradient stream. Under the USEPA method, embeddedness, velocity depth combinations, and the frequency of riffles (bends) are not assessed and the following parameters are substituted:

- Pool Substrate Characterization. Evaluates the type and condition of the bottom sediments found in pools. Optimal conditions are characterized by a mixture of substrate materials with root mats and submerged vegetation common. If the pool has a clay or bedrock substrate with no vegetation, the stream is assessed as poor.
- Pool Variability. There are four basic types of pools, large shallow; large deep; small shallow; and small deep. Streams rated optimal have all four varieties, those rated as poor are dominated by small shallow pools or lack pools.
- Channel Sinuosity. A high degree of sinuosity provides a diverse habitat and allows streams to more easily handle surges associated with flooding. Higher sinuosity is characteristic of optimal conditions.

2.8.2 Aquatic Life

Aquatic communities were sampled within the intermittent sections mitigation streams. Benthic macroinvertebrates are a primary food source not only for fish and salamanders, but for riparian birds and other animals which forage on both aquatic and terrestrial stages of aquatic insects and which can be essential to their survival (McCafferty, 1981). Thus, benthic macroinvertebrate surveys were conducted at the mitigation streams in conjunction with other biological surveys to serve as baseline data and to be continued during the monitoring period.

2.8.2.1 Benthic Macroinvertebrates

Many benthic macroinvertebrates are sensitive to changes in organic pollutants, sediments, and toxicants, and therefore, are widely used as a monitoring tool by many state water resource agencies (Southerland and Stribling 1995, EPA 2002). Unlike fish, benthic macroinvertebrates are not as mobile, and therefore, are more prone to reflect direct or short-term changes in water quality or habitat (Kuehne, 1962; Bartsch and Ingram, 1966; Wilhm and Dorris, 1968; Warren, 1971; Cairns and Pratt 1993). Their long life cycles allow conclusions to be made about the stream and watershed in regards to environmental quality. Measurements of richness and diversity relative to the chemical and physical characteristics of their environment provide very useful indices for baseline and monitoring studies (McCafferty 1981). Merritt and Cummins (1996) provides an outstanding list of reference resources to identify organisms, identify specific life histories, ecological treatments, and list excellent comments in regards to a particular benthic macroinvertebrate's importance to humans in regards to recreational fly fishing.

Benthic macroinvertebrates were sampled using USEPA's rapid bioassessment protocols. For purposes of mitigation monitoring, a multi-habitat approach was used to demonstrate the importance of habitat diversity for benthic macroinvertebrates. Monitoring of existing streams typically results in a general lack of instream habitats, compared to the same streams after improvements, where instream habitat diversity has increased dramatically. By using a multi-habitat approach, the benthic macroinvertebrate data can demonstrate this change in available habitat.

A multi-habitat approach is conducted by collecting a composite sample of 20 jabs or kicks using a rectangular dip net (0.5 m x 0.3 m). Major habitat types (cobble in riffles and runs, snags in pools, vegetated banks, submerged macrophytes, and sand) were sampled in a proportional representation within a 100 meter sampled reach (approximately 3.1 square meters of habitat). For example, if the sampling reach was comprised of 50% snags and 50% riffles, then 50% of the jabs/kicks (10) would be in snags and 50% of the jabs/kicks (10) would be in riffles. Sampling began at the downstream end of the reach and proceeded upstream. The composite sample was washed through with on-site water, while large rocks and large woody debris were discarded. The sample was transferred to a 1-liter container and preserved with 95% ethanol.

All collected organisms were sorted and identified to family level. Identification followed Merritt and Cummins (1996) for larval insects and Pennak (1989) for crustaceans and annelids. Data analysis included calculation of RBP metrics: total taxa; Ephemeroptera/Plecoptera/Trichoptera (EPT) taxa; percent EPT; percent Chironomidae, percent two dominant taxa; and Hilsenhoff Biotic Index (HBI; Table 2.4). West Virginia Stream Condition Index (WVSCI) values were calculated for each of the listed RBP metrics and averaged for a total WVSCI score (Gerritsen, et al., 2000). WVSCI scores range from 0 to 100 and were assigned a rank (Table 2.4). The Simpson's Diversity Index, as described in Section 2.9.4, was also calculated for benthic macroinvertebrates.

Table 2.4
Hilsenhoff Biotic Index (HBI) Ranges (Mandaville, 2002)

Biotic Index	Water Quality	Degree of Organic Pollution
0.00 – 3.50	Excellent	No apparent organic pollution
3.51 – 4.50	Very Good	Possible slight organic pollution
4.51 – 5.50	Good	Some organic pollution
5.51 – 6.50	Fair	Fairly significant organic pollution
6.51 – 7.50	Fairly Poor	Significant organic pollution
7.51 – 8.50	Poor	Very significant organic pollution
8.51 – 10.00	Very Poor	Severe organic pollution

2.9 Stream Design Parameter Selection Methodology

A combination of approaches to develop design criteria for channel dimension, pattern, and profile were used for this project. These approaches are described in the following sections. A flow chart for selecting design criteria is shown in Figure 2.7.

2.9.1 Upstream Reference Reaches

One option for developing design criteria is to locate a reference reach upstream of the project site. A reference reach is a channel segment that is stable—neither aggrading nor degrading—and is of the same morphological type as the channel under consideration for restoration. The reference reach should also have a similar valley slope as the project reach. The reference reach is then used as the blueprint for the channel design (Rosgen, 1998). To account for differences in drainage area and discharge between a reference site and a project site, data on channel characteristics (dimension, pattern, and profile), in the form of dimensionless ratios, are developed for the reference reach. If the reach upstream of the project does not have sufficient pattern, but does have a stable riffle cross-section, only dimension ratios are calculated. It is ideal to measure a reference bankfull dimension that was formed under the same environmental influences as the project reach, if available.

2.9.2 Reference Reach Searches

If a reference reach cannot be located upstream of the project reach, a review of a reference reach database is performed. A database search is conducted to locate known reference reaches in close proximity to the project site and includes streams with the same valley as the project reach and stream type as the design. If references are found meeting these criteria, the reference reach is field-surveyed for validation and comparison with the database values, which may have been originally collected and provided by a third party. If a search of the database reveals no references that meet the appropriate criteria, a field search is performed locally to identify a reference reach that has not yet been surveyed.

Potential reference reaches are identified by first evaluating USGS topographic quadrangles and aerial photography for an area. In general, the search is limited to subwatersheds within or adjacent to the project watershed. In certain cases, a reference reach may be identified farther away that matches the same valley and stream type as the proposed design of the project site. In such a case, care is taken to ensure that the potential reference reach lies within the same physiographic region as the project reach. Potential reference sites identified on maps are then evaluated in the field to determine if they are stable systems of the appropriate stream and valley type. If appropriate, reference reach surveys are conducted. When potential sites are located on private property, landowner permission is acquired prior to conducting any survey work.

2.9.3 Reference Reach Databases

If a reference reach is not found in close proximity to the project site, a reference reach database is consulted, and summary ratios are acquired for all streams with the same valley and stream type within the project's physiographic region. These ratios are then compared to literature values and regime equations, along with ratios developed through the evaluation of successful projects.

Due to the limited number of reference reaches near the project site, Baker has developed a reference reach database from its existing data. Stable riffle cross-sections in nearby watersheds with drainage areas below 1 square mile have been developed with dimension design criteria. Bankfull cross-sectional area and width have also been measured and then plotted as a function of the drainage area (regional curves, Figure 2.8 and Figure 2.9). The regional curves developed by Baker determine the dimension and the bankfull cross-sectional area for a given stream.

2.9.4 Regime Equations

A variety of published journals, books, and design manuals were used to cross reference database values with peer-reviewed regime equations. Examples include *Fluvial Forms and Processes* by David Knighton (1998), *Mountain Rivers* by Ellen Wohl (2000), and the *Hydraulic Design of Stream Restoration Projects* by the US Army Corps of Engineers (Copeland et al., 2001). One common regime equation used in our designs is the evaluation of pattern for design of meandering channels; for example, most reference reach surveys in the eastern United States show radius of curvature divided by bankfull width ratios much less than 1.5. The Corps manual recommends a ratio greater than 2.0 to maintain stability in free-forming systems. Since most stream restoration projects are constructed on floodplains denude of woody vegetation, we often use the Corps-recommended value rather than reference reach data. Meander wavelength and pool-to-pool spacing ratios are examples of other parameters that are sometimes designed with higher ratios than those observed on reference reaches, for reasons similar to those described for radius of curvature.

2.9.5 Comparison to Past Projects

All of the above techniques for developing ratios and/or regime equations are compared to past projects built under similar conditions. Ultimately, these sites provide the best pattern and profile ratios because they reflect site conditions after construction. While most reference reaches are in mature forests, restoration sites are in floodplains with little or no mature woody vegetation. This lack of mature woody vegetation severely alters floodplain processes and streambank conditions. If past ratios did not provide adequate stability or bedform diversity, they are not used; conversely, if past project ratios created stable channels with optimal bedform diversity, they will be incorporated into the design.

Ultimately, the design criteria are selections of ratios and equations made upon a thorough evaluation of the above tasks. Combinations of approaches may be used to optimize the design. The final selection of design criteria for the restoration site is discussed in Section 5.

2.10 Sediment Transport Competency and Capacity Methodology

Stream restoration designs must be tested to ensure that the new channel dimensions (in particular, the design bankfull mean depth) create a stream that has the ability to move its sediment load without aggrading or degrading over long periods of time. The ability of the stream to transport its total sediment load can be understood through two measures: sediment transport competency and sediment transport capacity. Competency is a stream's ability to move particles of a given size and is a measurement of force, often expressed as units of pounds per square foot (lbs/ft^2). Sediment transport capacity is a stream's ability to move a quantity of sediment and is a measurement of stream power, often expressed as units of watts/square meter. Sediment transport capacity is also calculated as a sediment transport rating curve, which provides an estimate of the quantity of total sediment load transported through a cross-section per unit of time. The curve is provided as a sediment transport rate in pounds per second (lbs/sec) versus discharge or stream power.

The total sediment load transported through a cross-section can be divided by type of movement into bedload and suspended load fractions. Bedload is generally composed of larger particles, such as course sand, gravels, and cobbles, which are transported by rolling, sliding, or hopping (saltating) along the bed. Suspended load is normally composed of fine sand, silt, and clay particles transported in the water column.

2.10.1 Competency Analysis

Median substrate size has an important influence on the mobility of particles in stream beds. Critical dimensionless shear stress (τ_{ci}) is the measure of force required to initiate general movement of particles in a bed of a given composition. At shear stresses exceeding this critical value, essentially all grain sizes are transported at rates in proportion to their presence in the bed (Wohl, 2000). τ_{ci} can be calculated for gravel bed stream reaches using surface and subsurface particle samples from a stable, representative riffle in the reach (Andrews, 1983). Critical dimensionless shear stress is calculated as follows (Rosgen, 2001b):

a) Calculate the ratio d_{50}/ds_{50}

where: d_{50} = median diameter of the riffle bed (from 100 count in riffle or pavement sample)
ds_{50} = median diameter of the bar sample (or subpavement)

If the ratio d_{50}/ds_{50} is between the values of 3.0 and 7.0, then calculate the critical dimensionless shear stress using Equation 1.

$$\tau_{ci} = 0.0834(d_{50}/ds_{50})^{-0.872} \qquad \textbf{(Equation 1)}$$

b) If the ratio d_{50}/ds_{50} is not between the values of 3.0 and 7.0, then calculate the ratio of D_i/d_{50}

where: D_i = largest particle from the bar sample (or subpavement)
d_{50} = median diameter of the riffle bed (from 100 count in the riffle or pavement sample)

If the ratio D_i/d_{50} is between the values of 1.3 and 3.0, then calculate the critical dimensionless shear stress using Equation 2.

$$\tau_{ci} = 0.0384(D_i/d_{50})^{-0.887} \qquad \textbf{(Equation 2)}$$

2.10.2 Aggradational Analysis

The aggradation analysis is based on calculations of the required depth and slope needed to transport large sediment particles, in this case defined as the largest particle of the riffle subpavement sample. Required depth can be compared with the existing/design mean riffle depth, and required slope can be compared to the existing and design slopes to verify that the stream has sufficient competency to move large particles (and thus prevent thalweg aggradation). The required depth and slope are calculated by:

$$d_r = \frac{1.65\tau_{ci}D_i}{S_e} \qquad \textbf{(Equation 3)}$$

$$s_r = \frac{1.65\tau_{ci}D_i}{d_e} \qquad \textbf{(Equation 4)}$$

where: d_r = required bankfull mean depth (ft)
d_e= design bankfull mean depth (ft)
1.65 = sediment density (submerged specific weight)
= density of sediment (2.65) – density of water (1.0)
τ_{ci} = critical dimensionless shear stress
D_i = largest particle from bar sample (or subpavement) (ft)
s_r = required bankfull water surface slope (ft/ft)
S_e = design bankfull water surface slope (ft/ft)

The aggradation analysis is used to assess both existing and design conditions; for example, if the calculated value for the existing critical depth is significantly larger than the measured maximum bankfull depth, this indicates that the stream is aggrading. Alternately, if the proposed design depth significantly differs from the calculated critical depth, and the analysis is deemed appropriate for the site conditions, the design dimensions should be revised accordingly.

2.10.3 Competency Analysis Using Shields Curve

As a complement to the required depth and slope calculations, boundary shear stresses for a design riffle cross-section can be compared with a modified Shields Curve to predict sediment transport competency. The shear stress placed on the sediment particles is the force that entrains and moves the particles, given by:

$$\tau = \gamma R s \qquad \textbf{(Equation 5)}$$

where: τ = shear stress (lb/ft^2)
γ = specific gravity of water (62.4 lb/ft^3)
R = hydraulic radius (ft)
s = average channel slope (ft/ft)

The boundary shear stress can be estimated for the design cross-section and plotted on a modified Shields curve, as shown in Figure 2.6. The particle size that Shields Curve predicts will be moved is compared to the D_i of the site subpavement. Shields Curve predicts whether the design conditions will have enough shear stress to move a particle larger than the largest subpavement particle found in the creek and prevent aggradation.

2.10.4 Degradation Analysis

A degradation analysis is performed in order to assess whether the design cross-sections will result in scour and bed downcutting. The potential for degradation may be evaluated by examining the upper competency limits for design cross-sections and by reviewing existing and design grade control at the site. The calculated shear stress discussed in Section 2.7.3 can be used to describe the upper competency limits for the design channel. The calculated shear stress is compared to the Modified Shields Curve to determine the largest particle size that stress value will move. This value should be comparable to the values from the reach-wide pebble count.

2.10.5 Sediment Transport Capacity

For fine grained stream beds, sediment transport capacity is much more important than competency. Sediment transport capacity refers to the stream's ability to move a mass of sediment past a cross-section per unit of time in pounds/second or tons/year. Sediment transport capacity can be assessed directly using actual monitored data from bankfull events if a sediment transport rating curve has been developed for the project site. Since this curve development is extremely difficult, other empirical relationships are used to assess sediment transport capacity. The most common capacity equation is stream power. Stream power can be calculated a number of ways, but the most common is the following:

$$w = \gamma QS/W_{bkf} \qquad \textbf{(Equation 6)}$$

where: w = mean stream power (W/m^2)
γ = specific weight of water 9,810 N/m^3); $\gamma = \rho g$, where ρ is the density of the water-sediment mixture (1,000 kg/m^3) and g is the acceleration due to gravity 9.81 m/s^2)
Q = bankfull discharge (m^3/s)
S = design channel slope (m/m)
Wbkf = bankfull channel width (m)
Note: 1 ft-lb/sec/ft^2 = 14.56 W/m^2

Equation 6 does not provide a sediment transport rating curve; however, it does describe the stream's ability to accomplish work, i.e., move sediment. Calculated stream power values are compared to reference and published values. If deviations from known stable values for similar stream types and slopes are observed, the design should be reassessed to confirm that sediment will be adequately transported through the system without containing excess energy in the channel.

2.11 In-Stream Structures

There are a variety of in-stream structural elements used in `. Figure 2.10 illustrates a few typical structures. These elements are comprised of natural materials, such as stone, wood, and live vegetation. Their shape and location works with the flow dynamics to reinforce, stabilize, and enhance the function of the stream channel. In-stream structures provide three primary functions: grade control, streambank protection, and habitat enhancement.

2.11.1 Grade Control

Grade control pertains mainly to the design bed profile. A newly excavated gravel stream bed with a slope greater than 0.5% is seldom able to maintain the desired slopes and bed features, such as riffles, runs, pools, and glides, until a pavement/subpavement layer has been established. Stone and/or log structures installed at the bed elevation and at critical locations in the plan view help to set up the new stream bed for long-term vertical stability. Over time, as the new channel adjusts to its sediment transport regime and vegetative root mass establishes on the banks, the need for grade control diminishes.

2.11.2 Bank Protection

Bank protection is critical during and after construction, as bank and floodplain vegetation is establishing a reinforcing root mass. This vegetation establishment lasts for several years, but vegetation typically provides meaningful bank protection after two to four growing seasons. Bank protection structures generally provide both reinforcement to the streambanks and re-direction of flow away from the banks and toward the center of the channel.

2.11.3 Habitat Enhancement

Habitat enhancement can take several forms and is often a secondary function of grade control and bank protection structures. Flow over vanes and wing deflectors create scour pools, which provide diversity of in-stream habitat. Boulder clusters form eddies that provide resting places for aquatic species. Vane structures and step pools encourage oxygenation of the water. Root wads provide cover and shade and encourage the formation of deep pools at the outside of meander bends.

2.11.4 Selection of Structure Types

Table 2.5 summarizes the names and functions of several in-stream structures.

Table 2.5
Functions of In-Stream Structures

Structure	Function (Primary = 1, Secondary = 2)		
	Grade Control	Bank Protection	Habitat Enhancement
Cross vane	1	1	2
Single arm vane		1	2
J-hook vane	2	1	2
Constructed riffle	1	1	2
Log weir	1		2
Wing deflector	2	1	1
Boulder cluster			1
Root wad		1	1
Brush mattress		1	2
Cover log			1

The selection of structure types and locations typically follows dimension, pattern, and profile design. In some situations, structures comprise the main, or possibly only, effort to restore a stream. More often, structures are used in conjunction with grading, realignment, and planting, in an effort to improve channel stability and aquatic habitat.

2.12 Stream and Buffer Vegetation

The planting of additional and/or more desirable vegetation is an important aspect of the restoration plan. Vegetation helps stabilize streambanks, creates habitat and food sources for wildlife, lowers water temperature by stream shading, improves water quality by filtering overland flows, and improves the aesthetics of the site.

The reforestation component of a restoration project may include live dormant staking of the streambanks, riparian buffer planting, invasive species removal, and seeding for erosion control. The streambanks and the riparian area are typically planted with both woody and herbaceous vegetation to establish a diverse streamside buffer. Planting the streambanks is a desirable means of erosion control because of the dynamic, adaptive, and self-repairing qualities of vegetation. Vegetative root systems stabilize channel banks by holding soil together, increasing porosity and infiltration, and reducing soil saturation through transpiration. During high flows, plants lie flat, and stems and leaves shield and protect the soil surface from erosion. In most settings, vegetation is more aesthetically appropriate than engineered stabilization structures.

The most appropriate source of plant material for any project is the site itself. If practical, desirable plants that need to be removed in the course of construction may be salvaged and transplanted as part of the restoration plan. Under some situations, native plant may be transplanted from areas nearby. This transplant process ensures that the plants are native and adapted to the locale. Most sites will require that some, if not all, plants be purchased from a commercial provider. They should be obtained from a nearby, reputable nursery that guarantees that the plants are native and appropriate for the locale and climate of the project site.

2.12.1 Live Staking

Live staking is a method of re-vegetation that utilizes live, dormant cuttings from appropriate species to establish vegetation cheaply and effectively. The installation of live stakes on streambanks serves to protect the banks from erosion and at the same time, provides habitat, shade, and improved aesthetics. Live staking must take place during the dormant season. Live stakes can be gathered locally or purchased from a commercial supplier. Stakes should be at least ½ inches and no more than 2 inches in diameter, between 2 and 3 feet in length, and living, as evidenced by the presence of young buds and green bark. Stakes are cut at an angle on the bottom end and driven into the ground with a rubber mallet.

2.12.2 Transplanted Vegetation

Transplanting is a method of removing desirable vegetation from one location on the project site and replanting it at another location on the site. In most cases, the vegetation being moved would otherwise be destroyed during restoration; for example, vegetation growing along the toe of a deeply incised channel would be destroyed when water was routed into a new stream channel and the old channel was backfilled. Transplanted vegetation provides immediate shading to the restored stream, as well as living root mass to increase streambank stability and create holding areas for fish and aquatic biota.

Transplants are excavated using a loader or mechanized excavator, such that the complete root mass and surrounding soil are removed intact. The transplant is then placed in an excavated hole along the streambank, generally around the outside of a meander bend, where establishment of vegetation is crucial to streambank stability.

2.12.3 Riparian Buffer Re-Vegetation

Riparian buffers are naturally occurring ecosystems adjacent to rivers and streams and provide numerous benefits and system functions. Buffers are important in nutrient and pollutant removal in overland flow and may provide for additional subsurface water quality improvement in the shallow groundwater flow. Buffers also provide habitat and travel corridors for wildlife populations and are an important recreational resource. It is also important to note that riparian buffer areas help to moderate the quantity and timing of runoff from the upland landscape and contribute to the groundwater recharge process.

Buffers are most valuable and effective when comprised of a combination of trees, shrubs, and herbaceous plants. Width generally increases the capacity of riparian buffers to improve water quality and provide habitat value (Fischer and Fischenich, 2000). An minimum width of 50 - 100 feet has been adopted for protection by many regulatory agencies as the required width for creating beneficial forest structure and riparian habitat (West Virginia Surface Mining Rule 38-02; North Carolina Administrative Code 15A NCAC 2B .0233).

In stream and wetland restoration, where buffer width is often limited, the following design principles apply:

- Design for sheet flow into and across the riparian buffer area.
- If possible, the width of the riparian buffer area should be proportional to the watershed area, the slope of the terrain, and the velocity of the flow through the buffer.
- Forest structure should include understory and canopy species. Canopy species are particularly important adjacent to waterways to moderate stream temperatures and to create habitat.

- Use native plants that are adapted to the site conditions (e.g., climate, soils, and hydrology). In suburban and urban settings, riparian forested buffers do not need to resemble natural ecosystems to improve water quality and habitat.

2.13 Risk Recognition

It is important to recognize the risks inherent in the assessment, design, and construction of environmental restoration projects. Such endeavors involve the interpretation of existing conditions to deduce appropriate design criteria, the application of those criteria to design, and most important, the execution of the construction phase. There are many factors that ultimately determine the success of these projects; many are beyond the influence of a designer, and compiling all of them is beyond the scope of this report. It is impossible to consider and to design for all of them, but it is important to acknowledge those factors, such as daily temperatures, amount and frequency of rainfall during and following construction, subsurface conditions, and changes in watershed characteristics, that are beyond the control of the designer.

Many restoration sites will require some post-construction maintenance, primarily because newly planted vegetation plays a large role in channel and floodplain stability. Stream restoration projects are most vulnerable to adjustment and erosion immediately after construction, before vegetation has had a chance to become fully established. Risk of instability diminishes with each growing season. Streams and floodplains usually become self-maintaining after the second year of growth, although unusually heavy floods often cause erosion, deposition, and/or loss of vegetation in even the most stable channels and forested floodplains.

3.0 WATERSHED ASSESSMENT RESULTS

3.1 Watershed Delineation

The project area encompasses portions of two subwatersheds of Cane Creek (hydrologic unit 05100204, Upper Kentucky River), including the Right Fork of Upper Cane Creek and Commissary Branch; along with their associated tributaries (Figure 1.2). Commissary Branch is the largest tributary with a 0.318 square mile (203.6 ac) drainage area, while Right Fork of Upper Cane Creek is 0.256 square miles (163.7 ac) drainage area (Table 3.1; Figure 1.3).

Table 3.1
Drainage Area Summary

Mitigation Reach	Acres	Square Miles
Right Fork of Upper Cane Creek	163.7	0.256
RUT1 of Right Fork Upper Cane Creek	45.3	0.071
LUT1 of Right Fork of Upper Cane Creek	12.2	0.019
Commissary Branch	203.6	0.318
RUT1 of Commissary Branch	37.1	0.058
RUT2 of Commissary Branch	19.5	0.031
LUT1 of Commissary Branch	3.8	0.006

3.2 Geology and Soils

3.2.1 Geology & Land Use

The proposed project area is located in portions of the Upper Cane Creek watershed, which flows from its headwaters in Menifee County, WV, in a southwesterly direction into and across Powell County, Kentucky. The Right Fork of Upper Cane Creek watershed lies within the Kanawha section of the Appalachian Plateaus physiographic province located in eastern Kentucky. The Kanawha section is grouped with Cumberland Mountain and Cumberland Plateau sections to form the Eastern Coal Field region (Figure 3.1).

In the vicinity of the project area, the stratigraphy of the Kanawha section is characterized by shales and sandstones of the Borden and Breathitt Formations (Figure 3.1). The area is relatively flat, moderately to heavily-dissected by narrow, steep-sloped, v-shaped valleys displaying a dendritic drainage pattern whose streams and rivers ultimately drain to the Ohio River, the major river system in the region. The major topographic features throughout the region range from moderately flat to hilly to mountainous uplands consisting of moderately wide to narrow ridges, knobs, and saddles separated by steep, narrow, deep valleys.

3.2.2 Soils

Soil types and profiles for the project area were researched using Natural Resources Conservation Service (NRCS) soil survey data for Menifee County, along with preliminary on-site evaluations, to determine soil characteristics in the project area (USDA, NRCS, WSS). A map depicting the boundaries of each soil type in project area is presented in Figure 3.2. There are two dominant soil types/complexes found within the project boundary; a discussion of each soil type is presented in Table 3.2 and Table 3.3.

The predominant soil series within the project area is mapped as Cranston. The Cranston series consists of coarse-loamy colluvium derived from shale and siltstone, with well drained soils. This soil type is neither hydric nor considered suitable for cultivation.

Table 3.2
Project Soil Types and Descriptions

Soil Name	Location	Description
Mitigation Reaches		
Brookside (BrF)	Upper valley bottom of Commissary Branch	Brookside soils make up 13 percent of the project area. The parent material consists of clayey colluvium derived from limestone. The depth to a restrictive feature is greater than 60 inches to bedrock. This soil is well drained. The slowest soil permeability within a depth of 60 inches is moderately slow. Available water capacity to a depth of 60 inches is moderately high, and shrink swell potential is moderate. Annual flooding is none, and annual ponding is none. The minimum depth to a water table is greater than 80 inches. It is non-irrigated land capability subclass 7s. This soil is not suitable for cultivated crops. This component is not a hydric soil.
Cranston (CrF)	Valley bottoms of Commissary Branch and Right Fork of Upper Cane Creek	Cranston soils make up 87 percent of the project area. The parent material consists of coarse-loamy colluvium derived from shale and siltstone. The depth to a restrictive feature is more than 80 inches to bedrock. This soil is well drained. The slowest soil permeability within a depth of 60 inches is high. Available water capacity to a depth of 60 inches is high, and shrink swell potential is low. Annual flooding is none, and annual ponding is none. The minimum depth to the top of the seasonal high water table is at 80 inches. It is non-irrigated land capability subclass 6e. This soil is not suitable for cultivated crops. This component is not a hydric soil.
Note: NRCS, USDA. Official Soil Series Descriptions (http://soils.usda.gov/soils/technical/classification/osd/index.html)		

Table 3.3
Project Soil Type Characteristics (NRCS, USDA. Official Soil Series Descriptions)

Series	Max Depth (in)	% Clay on Surface	K_{sat} (µm/sec)	T (tons/acre/year)	OM on surface / at depth %
Mitigation Reaches					
Brookside (BrF)	70	15-30	4.00-14.00	4	1.0-4.0 / 0-5
Cranston (CrF)	76	12-18	14.00-42.00	4	0.5-4.0/0-5
Note: NRCS, USDA. Official Soil Series Descriptions (http://soils.usda.gov/soils/technical/classification/osd/index.html)					

3.3 Vegetation

Mixed deciduous forest is the dominant land cover type within the proposed impact and mitigation project areas, and consists of three strata: canopy, understory, and herbaceous ground cover. The canopy strata consists of mixed-aged stands with occasional large diameter trees (approximately 50 inches dbh), with no old-growth forest remaining. Within each watershed, there are three (3) forest types including, oak-hickory, northern hardwoods, and bottomland hardwoods. The oak-hickory and northern hardwoods forest types are commonly found on the ridges and valley slopes of each watershed, and the bottomland hardwoods forest type is typically found on the valley floor (USDA, 1913).

The oak-hickory cover type is found generally along the drier south-east to south-west facing slopes. Dominant tree species include white oak (Quercus alba), chestnut oak (Quercus prinus), scarlet oak (*Quercus coccinea*), black oak (*Quercus velutina*), hickories (*Carya spp.*), black gum (*Nyssa sylvatica*), and red maple

(Acer rubrum). Virginia pine (Pinus virginiana), pitch pine (Pinus rigida), chestnut oak (*Quercus prinus*), and scarlet oak (Quercus coccinea) may be found along the ridge top (USDA, 1913).

The northern hardwoods cover type is found generally along the moist, partially shaded and well-drained north-west to north-east facing slopes. Dominant tree species consist primarily of tulip poplar (*Liriodendron tulipifera*), red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), basswood (*Tilia americana*), cucumber (*Magnolia accuminata*), black birch (*Betula lenta*), eastern hemlock (*Tsuga canadensis*), and scattered white oak (*Quercus alba*) (USDA, 1913).

The bottomland hardwoods cover type is generally found within the stream floodplains and along the stream bank. Sycamore (*Platanus occidentalis*), black walnut (*Juglans nigra*), basswood (*Tilia americana*), and willows (*Salix spp.*) are the dominant tree species. Associated woody plants in bottomlands also include witch-hazel (*Hamamelis virginiana*), spicebush (*Lindera benzion*), hazelnut (*Corylus americana*), pawpaw (*Asimina triloba*), red elm (*Ulmus rubra*) and American elm (*Ulmus americana*) (USDA, 1913).

Co-dominant, intermediate, and understory woody plants found in the watershed include flowering dogwood (*Cornus florida*), hawthorns (*Crataegus spp.*), black cherry (*Prunus serotina*), red bud (*Cercis canadensis*), mountain laurel (*Kalmia latifolia*), great rhododendron (*Rhododendron maximus*), mountain magnolia (*Magnolia fraserii*), musclewood (*Carpinus caroliniana*), and ironwood (*Diospyrus virginiana*) (USDA, 1913).

Non-woody shrubs and lateral climbing species found in the watershed include greenbrier (*Smilax spp.*), blackberry (*Rubus spp.*), honeysuckle (*Lonicera spp.*), grape vine (*Vitis spp.*), and poison ivy (*Toxicodendron radicans*) (USDA, 1913). The herbaceous layer consists of various flowering plants including golden ragwort (*Scencio aureus*), nettles (*Laportea spp.*), violets (*Viola spp.*), goldenrods (*Solidago spp.*), and various woodland grass, sedge, and rush species.

3.4 Climate

The proposed project area occurs in a continental humid temperate climatic type (Friel et al., 1984). The regional climatic characteristics are largely determined by the orogenic effect of the Appalachian Mountains, which creates a rain shadow on the leeward side of the mountains and channels maritime tropical air masses moving up from the south in a northeasterly direction along the mountains where they come into contact with continental polar air masses. The general climate is that of warm, humid summers and moderately cold, mild to severe winters, varying with elevation, with prevailing winds coming from the southwest. Average daily temperatures range from 18 to 86 degrees Fahrenheit. Evaporation rates are generally low, with precipitation being greater than evaporation (surplus), except during the summer and early fall months.

Although fairly well-distributed throughout the year, precipitation amounts are typically greater in late winter and early spring. The wettest months of the year generally are March, April, May, June, and July. In Menifee County, Kentucky, annual precipitation averages 47 inches, with monthly precipitation ranging from 3 to 5 inches during all months, with the exception of July when precipitation generally ranges between 5 to 6 inches. Snowfall averages 14 inches annually (NCDC, 2008). Precipitation in the project vicinity primarily develops from the movement of warm humid air from the south into Kentucky. Severe thunderstorms often form as these air masses meet land-based frontal systems. Tornadoes are a rarity in the region. The most severe storms generate precipitation over several days, creating moist watershed conditions. Significant flooding then may occur when more intense periods of precipitation fall within a day. The driest months are typically February, August, September, October, November, and December. Both short-term droughts and extended droughts occur periodically in the region. The shorter droughts have the potential to create severe damage as a result of their timing in relation to seasonal water needs.

3.5 Potential Constraints

The mitigation areas for the project area were assessed in regards to potential fatal flaws and site constraints. No major constraints or fatal flaws have been identified during project design development.

3.5.1 Property Ownership and Boundary

KY Fish & Wildlife has obtained site protection requirements with the on-site landowners, including Chip Culton, Dale Gough, Richard Shadwick, Randy Phipps, Dennis Phipps, and Ron Lutrell. Upon restoration and enhancement of the Right Fork of Upper Cane Creek and Commissary Branch, a 50-foot riparian buffer (25-feet on each streamside) will be protected in an easement (Appendix E).

As part of the stream restoration and enhancement plan, an existing county road (Pumpkin Hollow Road, County Route 208) will be relocated out of the streams. Therefore, an additional road easement will be in place along the new road alignment. The easement width will be a variable width based on construction limits, which includes an additional 5-foot buffer width. The road easement will then range from a minimum width of 25 feet to 100 feet in width (Appendix E).

3.5.2 Site Access

The project is located in the headwaters of the Right Fork of Upper Cane Creek at the end of Pumpkin Hollow Road, 6.6 miles northeast of Stanton, KY, in Menifee County. Take 11/15 east out of Stanton, left onto Route 1184, right onto Rt. 615, left onto Rt. 599, and then right onto Pumpkin Hollow Road. The project boundary begins near a gate and old logging area near the confluence of Commissary Branch and the Right Fork of Upper Cane Creek.

Temporary access roads constructed to gain access to the site, or otherwise required shall be kept to a minimum and only constructed upon approval from KY Fish & Wildlife. Temporary access roads shall be returned to the original or design contour as nearly as possible and revegetated according to Section 5.42 of this report.

3.5.3 Utilities

There are no known active utilities throughout the project area. However, there are some plugged and abandoned gas wells and lines. These areas will need to be verified and located by the selected contractor before construction is initiated.

4.0 STREAM CORRIDOR ASSESSMENT RESULTS

4.1 Reach Identification

4.1.1 Proposed Mitigation Areas

4.1.1.1 Right Fork of Upper Cane Creek

Existing condition data were collected within the representative reaches throughout the main stem of the Right Fork of Upper Cane Creek. There were a total of four (4) reaches defined by changes in drainage area throughout the Right Fork of Upper Cane Creek. Three tributaries were observed throughout the main stem, including one right tributary and two left tributaries (looking upstream). One representative reach was evaluated on the right tributary, referred to as RUT1 of Right Fork of Upper Cane Creek. Existing conditions of the representative reaches sampled in the project area were used in conjunction with reference and regional curve data for design purposes of the restoration and enhancement areas (Figure 1.3).

4.1.1.2 Commissary Branch

Existing condition data were collected within the representative reaches throughout the main stem of Commissary Branch. There were a total of three (3) reaches defined by changes in drainage area throughout Commissary Branch. Four tributaries were observed throughout the main stem, including two right tributaries and two left tributaries (looking upstream). Existing conditions of the representative reaches sampled in the project area were used in conjunction with reference and regional curve data for design purposes of the restoration and enhancement areas.

4.2 Hydrologic and Hydraulic Assessment

4.2.1 Watershed Hydrology

Discharges for the restoration and enhancement reaches were calculated by the Regional Regression Equations as detailed in *Estimating Magnitude and Frequency of Peak Discharges for Rural, Unregulated Streams in West Virginia* (WRI Report 00-4080). Because the project area is located in Eastern Kentucky and is located within the same physiographic region as those streams studied in the report described above, Baker used this tool for watershed hydrology assessments.

Table 4.1 shows the discharges calculated for the 1.1-, 1.2-, 1.3-, 1.4-, 1.5-, 1.6- , 1.7-, 1.8-, 1.9-, 2-, 5-, 10-, 25-, 50, and 100-year recurrence intervals on the Right Fork of Upper Cane Creek and Commissary Branch. Because only enhancement is proposed on the unnamed tributaries, hydrology calculations were not conducted. These discharges are necessary to complete the hydraulic and sediment transport analyses, which describe the stream's ability to move water and sediment. These functions were evaluated by quantifying factors such as bankfull discharge, channel geometry (i.e., size, shape, and slope), flow regime, velocity, shear stress, and sediment transport capacity, which are discussed in the Section 4.2.1.2 (hydraulics) and Section 4.3 (geomorphology). The purpose of these analyses was to demonstrate a functional lift by comparing the results for the impaired streams (existing conditions) versus the improved streams (proposed or design conditions).

Table 4.1
Discharges for Proposed Mitigation Reaches

Return Interval (years)	Discharges (cfs)			
	Right Fork of Upper Cane Creek		Commissary Branch[1]	
	Reach 1 & 2	Reach 3 & 4	Reach 1	Reach 3
1.1	16	9	19	11
1.2	19	11	23	14
1.3	22	13	26	16
1.4	24	14	29	17
1.5	26	15	31	19
1.6	28	16	33	20
1.7	29	17	34	21
1.8	31	18	36	22
1.9	32	19	38	23
2	33	19	39	24
5	54	32	63	39
10	70	41	82	51
25	92	55	108	67
50	110	65	129	80
100	129	77	150	94

[1] Reach 2 of Commissary Branch has same hydrology as 'Reach 1 & 2' of Right Fork of Upper Cane Creek

4.2.2 Channel Hydraulics

Hydraulic functions of a channel primarily include flow capacity and sediment transport. These two main factors also have direct affects on many other stream functions including: floodplain benefits, bank stability, substrate composition, water chemistry, aquatic habitat, and groundwater interface. For the scope of this project, given the type of stream enhancement, it was deemed that a qualitative analysis of channel hydraulics would be sufficient. Observations of the stream channel suggest that the current channel dimensions are appropriate to provide a flow capacity that will result in a stable channel form; likewise observations suggest that the overall sediment transport characteristics of the reach are appropriate for the stream type.

4.3 Geomorphic Assessment

A geomorphic assessment was completed to compliment the hydrology and hydraulic analysis in Section 4.2 and to determine stream stability (vertical and lateral) and bedform diversity. More specifically, the hydrology, hydraulic and geomorphic processes work together to create the channel geometry or form. Longitudinal and cross-section surveys were performed in representative reaches as described in Section 4.1 throughout the project area. In addition, bed material samples were collected to classify the stream and perform sediment transport analyses. The following sections of this report summarize the survey results. Surveyed cross-sections, profiles, and sediment data are included in Appendix F. A photo log of each of the streams and their representative reaches is included in Appendix G.

4.3.1 Classification

Throughout the proposed project area there were a total of three stream types identified in the subwatersheds, including F4b, B4, and A4. Right Fork of Upper Cane Creek and Commissary Branch were classified as either the F4b or B4 stream types depending on the degree of confinement. The unnamed tributaries of each stream were classified as A4 stream types.

In general, the Rosgen A and B stream types began to develop more pools as channel gradient decreased, functioning like a step pool system. The Rosgen F channels have very long riffle lengths and low pool frequency, causing poor bedform diversity.

Stream channel definition and bedform diversity generally appear to be related to slope and watershed size. Most of the streams are beginning at a steep gradient with negligible channel definition. Definition and bedform diversity increase as surface runoff and watershed size increases. Large bed material and low stream flows provide channel and bank stability. Bedrock outcroppings are common in the steep narrow valleys,

4.3.1.1 Right Fork of Upper Cane Creek & Unnamed Tributaries

Rosgen A Channel

One of the right hand tributaries of the Right Fork of Upper Cane Creek, referred to as RUT1 of Right Fork of Upper Cane Creek was surveyed. The stream was classified as a Rosgen A4 stream type. The dimension surveys showed an entrenchment ratio (ER) of 3.0 and width/depth ratio of 6.5. The ER was larger than expected for this stream type due to artificial grading of the hillside from the parallalling county road. Profile surveys indicated sinuosity in the channel was 1.2. Average valley slope was 0.093 (9.3%) and channel slope averaged 0.078 (7.8%). The median particle size was 30 mm.

Rosgen B/F Channels

Throughout the reaches of Right Fork of Upper Cane Creek, the stream was classified as either a Rosgen F4b or B4 channel. Throughout the channel, dimension surveys showed entrenchment ratios (ERs) ranged from 1.2 to 1.3 and width/depth ratios ranged from 6.3 to 18.7. Profile surveys indicated sinuosity in the channel averaged 1.21. Average valley slope was 0.030 (3.0%) and channel slope averaged 0.036 (3.6%). The median particle size ranged from 25 to 35 mm.

4.3.1.2 Commissary Branch & Unnamed Tributaries

Rosgen A Channel

One of the right tributaries of the Commissary Branch, referred to as RUT2 of Right Fork of Upper Cane Creek was surveyed. The stream was classified as a Rosgen A4 stream type. The dimension surveys showed an entrenchment ratio (ER) of 2.7 and width/depth ratio of 7.4. The ER was larger than expected for this stream type due to artificial grading of the hillside from the parallalling ATV/logging road. A profile surveys was not conducted on this segment of stream. The median particle size was 30 mm.

Rosgen B/F Channels

Throughout the reaches of Commissary Branch, the stream was classified as either a Rosgen F4b or B4 channel. Throughout the channel, dimension surveys showed entrenchment ratios (ERs) ranged from 1.3 to 2.1 and width/depth ratios ranged from 5.9 to 24.9, with an average of 12.4. The width/depth ratios significantly larger than 12 are the overly wide stream channels and are classified as Rosgen F channels. Profile surveys indicated sinuosity in the channel averaged 1.22. Average valley slope was 0.039 (3.9%)

and channel slope averaged 0.034 (3.4%). The median particle size ranged from 31 to 48 mm.

4.3.2 Bedform Diversity

Existing conditions data (Table 4.2) of the geomorphic characterization study, including review of the longitudinal profile survey indicates bedform diversity and in-stream habitat is not extremely poor; however it is not ideal at the restoration areas and can be enhanced upon. Longitudinal data shows that within the Rosgen A channel type (unnamed tributaries) had 65% riffle and 35% pool. Rosgen B/F channel types (Right Fork of Upper Cane Creek, Commissary Branch) had an average of 86% riffle and 14% pool. Pool-to-pool spacing in the Right Fork of Upper Cane Creek averaged 127 feet apart, where design criteria specify a maximum of 42, indicating there is a general lack of pools. Commissary Branch is similar in that it has an average pool-to-pool spacing of 78 feet, while design criteria specify a maximum of 45 feet apart.

The goal of the restoration of these areas is to obtain a more balanced riffle and pool ratio creating a more step pool system in these stream types. In order to do so, the channel will be restored in sections, while in-stream habitat in the form of rock and log structures will be installed throughout. Channel restoration with the addition of in-stream structures is expected to obtain the natural balance of riffle and pool ratios these stream types typically exhibit.

Table 4.2
Existing Conditions Geomorphic / Stream Classification Data

Parameter		Upper Cane Creek			Commissary Branch (Reaches 1 and 2)			Commissary Branch (Reach 3)	RUT2 of Commissary Branch
		Min	Max	Average	Min	Max	Average		
Rosgen Stream Type		F4b			B4			A	A
Drainage Area (sq mi)		----	----	0.3	----	----	0.3	0.1	0.0
Reach Length Surveyed (ft)		----	----	3432.5	----	----	2734.0	----	----
Dimension	Bankfull Width (ft)	6.3	8.2	7.5	10.6	15.7	13.1	5.5	7.8
	Bankfull Mean Depth (ft)	0.4	1.0	0.6	0.6	0.8	0.7	0.9	1.0
	Width/Depth Ratio	6.3	18.7	14.3	14.0	24.9	19.4	5.9	7.4
	Bankfull Area (sq ft)	3.4	6.2	4.4	8.0	9.8	8.9	5.0	8.3
	Bankfull Max Depth (ft)	0.6	1.3	0.9	1.0	1.1	1.1	1.4	1.8
	Width of Floodprone Area (ft)	8.6	10.3	9.4	14.4	19.6	17.0	11.5	21.0
	Entrenchment Ratio	1.2	1.4	1.3	1.3	1.4	1.3	2.1	2.7
	Max Pool Depth (ft)	0.5	1.1	0.8	0.9	1.7	1.4	----	----
	Ratio of Max Pool Depth to Bankfull Depth	0.9	1.8	1.3	1.3	2.4	2.1	----	----
	Pool Width (ft)	7.5	8.3	8.0	9.0	10.1	9.4	----	----
	Ratio of Pool Width to Bankfull Width	1.0	1.1	1.1	0.7	0.8	0.7	----	----
	Pool to Pool Spacing (ft)	17.9	448.8	127.2	1.2	139.6	78.4	----	----
	Ratio of Pool to Pool Spacing to Bankfull Width	2.4	60.1	17.0	0.1	12.1	6.8	----	----
	Bank Height Ratio	1.7	2.3	2.0	1.8	2.6	2.2	1.0	1.0
Pattern	Sinuosity	----	----	1.21	----	----	1.22	----	----
Profile	Valley Slope (ft/ft)	----	----	0.0304	----	----	0.0394	----	----
	WS Slope (ft/ft)	----	----	0.0367	----	----	0.0324	----	----
	Channel Slope	----	----	0.0362	----	----	0.034	----	----
	Pool Slope (ft/ft)	0.000	0.016	0.008	0.001	0.012	0.006	----	----
	Ratio of Pool Slope to WS Slope	0.00	0.45	0.22	0.02	0.38	0.20	----	----

4.3.3 Lateral Stability

The potential for streambank erosion was assessed by Kentucky Fish & Wildlife using the Bank Erosion Hazard Index (BEHI) analysis (Rosgen, 1994), as described in Section 2.6.3. BEHI was assessed in one of the channelized sections of the Right Fork of Upper Cane Creek located near the downstream end of the project. The BEHI value was a 38.0, indicating there is a high erosion rate in this particular reach of the Right Fork of Upper Cane Creek.

Although not measured throughout the entire project lengths, there appears to be varying degrees of erosion throughout the streams. The channelized segments, where pattern has been altered, appear to be contributing the most sediment to the stream, while the undisturbed areas are relatively stable. The restoration and enhancement efforts proposed will focus on the high erosional areas throughout the project.

4.3.4 Vertical Stability

Bed material samples were collected from a variety of reaches along Right Fork of Upper Cane Creek and Commissary Branch that were proposed for restoration. It appears that a large portion of these channels are used for all terrain vehicles (ATV). This ATV traffic has disturbed the natural sorting of the bed material, making it difficult to collect pavement / subpavement samples that are required for critical depth and slope calculations.

The boundary shear stress was calculated for each reach and the particle size that should be mobile during a bankfull event was predicted using the EPA competency curve (USEPA; 2005). This predicted value was then compared to the D84 of the bed material to assess vertical stability. The results are shown in Table 4.3. Due to past channelization, the reaches are prone to incise, however there is a large amount of surface bedrock resulting in the inability of the streams to incise further. As a result of these processes, however, overall in-stream habitat and bedform diversity is not optimal.

Table 4.3
Sediment Transport Competency Analysis

Location		Boundary Shear Stress (lb/sq ft)	Grain Diameter (mm) EPA curve	D84 (mm)	D95 (mm)
Right Fork of Upper Cane Creek	Reach 1	0.77	200	96	92
	Reach 2	1.48	220	61	90
	Reach 3	0.38	100	71	90
Commissary Branch	Reach 1	2.56	500	60	110
	Reach 2	1.06	150	76	110
	Reach 3	3.05	249	78	120

4.4 Biotic Assessment

As discussed in Chapter 2 of this report, a number of different biotic assessments were conducted throughout the project area. Biotic assessments included stream habitat assessments, benthic macroinvertebrate surveys, and water quality.

4.4.1 Stream Habitat, Benthic Macroinvertebrates, & Water Quality

A total of five (5) sampling stations were identified within the project area, including three (3) stations in Right Fork of Upper Cane Creek and two (2) stations in Commissary Branch. At each of the sampling locations, habitat, benthic macroinvertebrate, and water quality data were collected. The location and elevation of each sampling station were recorded by global positioning system (GPS), and verified by using United States Geological Survey 7.5 minute topographic quadrangle maps. The sampling stations are referred to as:

- Right Fork of Upper Cane Creek - Upstream
- Right Fork of Upper Cane Creek - Downstream
- Right Fork of Upper Cane Creek – Below Project Area
- Commissary Branch - Upstream
- Commissary Branch – Downstream

4.4.1.1 Right Fork of Upper Cane Creek - Upstream

This station, referred to as Right Fork of Upper Cane Creek - Upstream, was located on Right Fork of Upper Cane Creek, approximately 2,180 feet upstream from the confluence with Commissary Branch (Figure 4.1). The station was 1,000 feet in elevation and located approximately at 37°54’26.8” N latitude and 83°44’27.8” W longitude. At this particular station, Right Fork of Upper Cane Creek was an intermittent, second order stream. Below is a summary of the pertinent physical, biological, and chemical parameters (Table 4.4). Additional surface water quality parameters are located in Appendix H.

Table 4.4
Summary of Physical, Biological, and Chemical Parameters

Right Fork of Upper Cane Creek - Upstream			
mHBI	pH	Conductivity	HAV
3.7	7.7	240	133

The multihabitat sampling conducted showed the total abundance of benthic macroinvertebrates at this station was comprised of 673 individuals, representing 24 taxa, including 12 EPT taxa (Appendix H). The EPT taxa were overall very intolerant. Although the highest tolerance value was 5 out of 10, which is the most tolerant; there were two taxa present that had a tolerance value of 0 out of 10 (Appendix H). The EPT taxa represented 48% of the population. The combined percent of Chironomidae and Oligochaeta was 3%, while the percent of primary clingers was 10%. The mHBI score was 3.7, indicating there was “very good” water quality with “possible slight organic pollution” (Table 4.4). Simpson’s Index indicated that the sampling station had an index of 0.785.

The proportion of habitat in the 100 meter sampling reach was comprised of 75% riffles, 20% snags, and 5% sand (Appendix H). Habitat assessments yielded a total HAV score of 133 (Appendix H). In-stream habitat was optimal, although only three of the four velocity/depth regimes were present. There was some slight channelization, as a road paralleled and crossed the stream. Banks had sub-optimal stability and immediate bank vegetation. The riparian vegetative zone was optimal on the left bank and very narrow on the right bank, due to the paralleling road.

4.4.1.2 Right Fork of Upper Cane Creek - Downstream

This station, referred to as Right Fork of Upper Cane Creek - Downstream, was located on Right Fork of Upper Cane Creek, approximately 710 feet upstream from the confluence with Commissary Branch (Figure 4.1). The station was 857 feet in elevation and located approximately at 37°54'15.9" N latitude and 83°44'20.1" W longitude. At this particular station, Right Fork of Upper Cane Creek was an intermittent, second order stream. Below is a summary of the pertinent physical, biological, and chemical parameters (Table 4.5). Additional surface water quality parameters are located in Appendix H.

Table 4.5
Summary of Physical, Biological, and Chemical Parameters

Right Fork of Upper Cane Creek - Downstream			
mHBI	**pH**	**Conductivity**	**HAV**
4.1	7.8	200	142

The multihabitat sampling conducted showed the total abundance of benthic macroinvertebrates at this station was comprised of 839 individuals, representing 21 taxa, including 10 EPT taxa (Appendix H). Overall, the EPT taxa were intolerant. Although the highest tolerance value was 4 out of 10, which is the most tolerant; there was a taxon present that had a tolerance value of 0 out of 10 (Appendix H). The EPT taxa represented 36% of the population. The combined percent of Chironomidae and Oligochaeta was 5%, while the percent of primary clingers was 15%.

The HBI score was 4.1, indicating there was "very good" water quality and "possible slight organic pollution" (Table 4.5). Simpson's Index indicated that the sampling station had an index of 0.703.

The proportion of habitat in the 100 meter sampling reach was comprised of 85% riffles, 10% sand, and 5% snags (Appendix H). Habitat assessments yielded a total HAV score of 142 (Appendix H). In-stream habitat was optimal, although only three of the four velocity/depth regimes were present. There was some slight channelization, as a road paralleled and crossed the stream. Banks had optimal stability and immediate bank vegetation. The riparian vegetative zone was optimal on the right bank and very narrow on the left bank, due to the paralleling road.

4.4.1.3 Right Fork of Upper Cane Creek – Below Project Boundary

This station, referred to as Right Fork of Upper Cane Creek – Below Project Boundary, was located on Right Fork of Upper Cane Creek, approximately 700 feet downstream from the confluence with Commissary Branch and outside of the project boundary (Figure 4.1). The station was 899 feet in elevation and located approximately at 37°54'4.3" N latitude and 83°44'24.0" W longitude. At this particular station, Right Fork of Upper Cane Creek was a perennial, third order stream. Below is a summary of the pertinent physical, biological, and chemical parameters (Table 4.6). Additional surface water quality parameters are located in Appendix H.

Table 4.6
Summary of Physical, Biological, and Chemical Parameters

Right Fork of Upper Cane Creek - Reference			
mHBI	**pH**	**Conductivity**	**HAV**
3.5	7.6	160	126

The multihabitat sampling conducted showed the total abundance of benthic macroinvertebrates at this station was comprised of 792 individuals, representing 21 taxa, including 11 EPT taxa (Appendix H). Overall, the EPT taxa were intolerant. Although the highest tolerance value was 4 out of 10, which is the most tolerant; there was a taxon present that had a tolerance value of 0 out of 10 (Appendix H). The EPT taxa represented 79% of the population. The combined percent of Chironomidae and Oligochaeta was 2%, while the percent of primary clingers was 37%. The HBI score was 3.5, indicating there was “very good” water quality with “possible slight organic pollution” (Table 1). Simpson’s Index indicated that the sampling station had an index of 0.800.

The proportion of habitat in the 100 meter sampling reach was comprised of 70% riffles, 25% snags, and 5% sand (Appendix H). Part of this sampling reach had bedrock control. Habitat assessments yielded a total HAV score of 126 (Appendix H). In-stream habitat was optimal, although there was some excess sediment, which caused slight embeddedness and areas with bedrock control. Banks had sub-optimal stability, with optimal immediate bank vegetation. The riparian vegetative zone on the right bank was optimal, while the riparian vegetative zone on the left bank was very narrow, due to a paralleling road.

4.4.1.4 Commissary Branch – Upstream

This station, referred to as Commissary Branch - Upstream, was located on Commissary Branch, approximately 2,090 feet upstream from the confluence with Right Fork of Upper Cane Creek (Figure 4.1). The station was 1,035 feet in elevation and located approximately at 37°54’21.4” N latitude and 83°43’57.0” W longitude.

At this particular station, Commissary Branch was an intermittent, second order stream. Below is a summary of the pertinent physical, biological, and chemical parameters (Table 4.7). Additional surface water quality parameters are located in Appendix H.

Table 4.7
Summary of Physical, Biological, and Chemical Parameters

Commissary Branch - Upstream			
mHBI	pH	Conductivity	HAV
3.7	7.4	120	127

The multihabitat sampling conducted showed the total abundance of benthic macroinvertebrates at this station was comprised of 879 individuals, representing 26 taxa, including 14 EPT taxa (Appendix H). The EPT taxa were overall intolerant. Although the highest tolerance value was 6 out of 10, which is the most tolerant; there were two different taxa present that had a tolerance value of 0 out of 10 (Appendix H). The EPT taxa represented 49% of the population. The combined percent of Chironomidae and Oligochaeta was 5%, while the percent of primary clingers was 25%. The HBI score was 3.7, indicating there was “very good” water quality with “possible slight organic pollution” (Table 4.7). Simpson’s Index indicated that the sampling station had an index of 0.801.

The proportion of habitat in the 100 meter sampling reach was comprised of 85% riffles and 15% snags (Appendix H). Habitat assessments yielded a total HAV score of 127 (Appendix H). The in-stream habitat was sub-optimal, as there was some excess sedimentation and embeddedness. Riffle frequency was moderate. Banks had sub-optimal stability and immediate bank vegetation. The riparian vegetative zones were sub-optimal, as an old road paralleled the stream.

4.4.1.5 Commissary Branch – Downstream

This station, referred to as Commissary Branch - Downstream, was located on Commissary Branch, approximately 710 feet upstream from the confluence with Right Fork of Upper Cane Creek (Figure 4.1). The station was 941 feet in elevation and located approximately at 37°54'12.1" N latitude and 83°44'10.1" W longitude. At this particular station, Commissary Branch was an intermittent, second order stream. Below is a summary of the pertinent physical, biological, and chemical parameters (Table 4.8). Additional surface water quality parameters are located in Appendix H.

Table 4.8
Summary of Physical, Biological, and Chemical Parameters

Commissary Branch - Downstream			
mHBI	**pH**	**Conductivity**	**HAV**
3.7	7.1	120	127

The multihabitat sampling conducted showed the total abundance of benthic macroinvertebrates at this station was comprised of 1,121 individuals, representing 26 taxa, including 14 EPT taxa (Appendix H). The EPT taxa were overall very intolerant. Although the highest tolerance value was 5 out of 10, which is the most tolerant; there were two taxa present that had a tolerance value of 0 out of 10 (Appendix H). The EPT taxa represented 65% of the population. The combined percent of Chironomidae and Oligochaeta was 4%, while the percent of primary clingers was 23%. The HBI score was 3.7, indicating there was "very good" water quality with "possible slight organic pollution" (Table 4.8). Simpson's Index indicated that the sampling station had an index of 0.774.

The proportion of habitat in the 100 feet sampling reach was comprised of 75% riffle, 10% vegetated banks, 10% snags, and 5% sand (Appendix H). Habitat assessments yielded a total HAV score of 127 (Appendix H).

The in-stream habitat was optimal, although there was some excess sedimentation and embeddedness. The left bank had moderate stability and the right bank had sub-optimal stability. Both banks had sub-optimal immediate bank vegetation. The riparian vegetative zone of the left bank was optimal, while the riparian vegetative zone was moderate on the right bank, due to a paralleling road.

5.0 RESTORATION DESIGN

Section 5.0 describes the restoration design for the Right Fork of Upper Cane Creek and Commissary Branch. Each of the restoration reaches was divided into reaches, due to a change in drainage area (Figure 1.3). Several of the unnamed tributaries of both streams will be enhanced by installing in-stream structures for increased bedform diversity and in-stream habitat. This restoration and enhancement approach will restore a variety of aquatic and terrestrial functions throughout the Right Fork of Upper Cane watershed.

5.1 Potential for Restoration and Enhancement

The restoration and enhancement approach for the Right Fork of Upper Cane Creek and Commissary Branch considers the potential of each reach, with the overall goal of improving impaired functions. The discussion below describes how the design will improve geomorphology, hydrology and hydraulics, biotic conditions, and water quality in the restored reaches. Often, a design aspect can provide a functional lift for more than one function, e.g., in-stream structures provide improved aquatic habitat, but also have a positive effect on geomorphology by providing bed and/or bank stability. In such cases, the discussion for the particular design aspect appears under the heading of the function that it has the greatest effect upon.

As shown in Section 4.0, the mitigation sites chosen for the project are appropriate candidates for restoration and enhancement because the channels have very poor bedform diversity, bank erosion, and poor in-stream habitat, as shown with the existing habitat assessment scores. The channel has past channel alterations throughout the majority of the reaches due to a county and ATV road, which forced the channels to their valley sides. Restoring proper pattern, profile, and dimension, while moving the roads out of the stream valleys will help to stabilize the channel bed and banks, improve sediment transport function, increase floodplain functions, and improve bedform diversity and aquatic habitats, such as riffles and pools.

5.1.1 Right Fork of Upper Cane Creek

The design approach on the mainstem of the Right Fork of Upper Cane Creek is targeted at relocating the existing county road out of the stream valley and onto an adjacent upland area to restore the stream to its historic alignment and profile. Due to the past channelization, the channel has been overwidened causing it to classify as a Rosgen F4b in locations. The restored channel will be designed to its historic classification, a Rosgen B4 channel. By reclaiming the road throughout the valley, immediate bank vegetation and riparian zones will then be re-established providing a natural riparian buffer for floodplain stability and storage, as well as providing terrestrial habitat and organic inputs to the stream.

5.1.2 Commissary Branch

The design for Commissary Branch includes reclaiming an abandoned ATV and logging road, which runs adjacent to the stream. As part of the restoration approach, the paralleling soil road will be reclaimed by regrading the floodplain and upland areas, while planting native riparian vegetation along the corridor. In areas where the roads have caused channelization, resulting in bank erosion, these sections of channel will be restored. Throughout the remaining portions of Commissary Branch the channel will be enhanced with in-stream structures to improve bedform diversity and in-stream habitat to re-establish its historic step pool system. Bankfull bench will also be created to improve floodplain storage and bank stability.

5.1.3 Unnamed Tributaries

Unnamed tributaries of both Right Fork of Upper Cane Creek and Commissary Branch will be enhanced by installing in-stream structures throughout the first few feet of stream. The purpose of this mitigation effort is to improve overall bedform diversity in these accessible reaches and to improve overall in-stream habitat near the confluences with the main stems. In-stream structures will be installed to mimic a step pool system in each of the unnamed tributaries of Right Fork of Upper Cane Creek and Commissary Branch.

5.2 Design Rationale – Geomorphology

Specific design parameters were developed using a combination of reference reach data, evaluation of past projects, analytical models, and best professional judgment. A description of the design rationale is provided in this section for each of the project reaches. See the Project Plan Sheets (Appendix I) for detailed design information on the mitigation reaches.

5.2.1 Design Criteria

An undisturbed reference reach for dimension, pattern, and profile could not be found in close proximity to the project site. However, stable riffle cross-sections in nearby watersheds with drainage areas below 1 square mile were used to develop dimension design criteria. Bankfull cross-sectional area and width were measure and then plotted as a function of the drainage area (regional curves, Figure 2.8 and Figure 2.9). The developed regional curves were used to determine the dimension, especially the bankfull cross-sectional area, for each of the mitigation stream reaches.

An evaluation of past projects and compilation of reference reach data were used to create a set of design criteria for colluvial channels (B stream types). The results from this evaluation are shown in Table 5.1. These results represent an evaluation of a reference reach database published by the North Carolina Department of Transportation along with the evaluation of over twenty Baker Engineering projects, including six projects that have been monitored for over five years and have experienced two hurricanes.

Table 5.1
Design Criteria for B Stream Types

Parameter	Design Ratios	
	Minimum	Maximum
Stream Type (Rosgen)	B4	
Width to Depth Ratio, W/D (ft/ft)	12.0	18.0
Riffle Max Depth Ratio, Dmax/Dbkf	1.1	1.4
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.2
Meander Length Ratio, Lm/Wbkf	N/a	N/a
Rc Ratio, Rc/Wbkf	N/a	N/a
Meander Width Ratio, Wblt/Wbkf	N/a	N/a
Sinuosity, K	1.1	1.2
Valley Slope, Sval (ft/ft)	0.020	0.04*
Riffle Slope Ratio, Srif/Schan	1.2	2.5
Run Slope Ratio, Srun/Srif	N/a	N/a
Glide Slope Ratio, Sglide/Schan	0.3	0.5
Pool Slope Ratio, Spool/Schan	0.0	0.4
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.0	3.5
Pool Width Ratio, Wpool/Wbkf	1.1	1.5
Pool-Pool Spacing Ratio, Lps/Wbkf	1.5	5.0

* For slopes greater than 4%, the Pool-Pool Spacing will be decreased

5.2.1.1 Right Fork of Upper Cane Creek & Commissary Branch - Overview

Based on the existing condition survey, both the Right Fork of Upper Cane Creek and Commissary Branch have similar morphologys and stable results. Upon review of the data, each stream will be designed as a Rosgen B4 stream type.

Selected design criteria are listed in Table 5.2. The design includes channel dimensions that only transport the bankfull discharge. All higher discharges will flow onto the adjacent floodprone area, providing storage for water and sediment. Although there is not much new channel pattern and profile design, those areas are designed to increase aquatic habitats and to create a diverse bedform of alternating riffle/steps and pools. Together, channel dimension, pattern, and profile are designed to create a channel that doesn't degrade or aggrade over time, while creating a variety of aquatic habitats.

In-stream structures will also be used to enhance the natural channel design. A combination of rock and log cross vanes, step pools, and rootwads will be used to provide grade control, improve bedform diversity, and re-introduce large woody debris. Erosion control matting, live stakes, bareroots, and transplants will be used to stabilize banks and facilitate a riparian buffer zone.

Before filling the old channel with excavated material from the new channel, cobble, gravel, and any available large boulders shall be salvaged and stockpiled. Boulders will be used in structures, while the salvaged cobble and gravel will be used in new channel riffles. The old channel areas will then be re-seeded with permanent and temporary grasses. Portions of the old channel may remain as depression areas to improve wetland functions. After construction, proposed stream channel crossings will be installed as rip-rap ford crossings.

Table 5.2
Design Parameters and Proposed Geomorphic Characteristics

Parameter	Right Fork of Upper Cane Creek Reaches 1 & 2		Right Fork of Upper Cane Creek Reaches 3 & 4		RUT1 of Right Fork of Upper Cane Creek		Commissary Branch Reach 1		Commissary Branch Reach 2		Commissary Branch Reach 3	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Drainage Area, DA (sq mi)	0.26		0.13		0.07		0.32		0.26		0.17	
Stream Type (Rosgen)	B4		B4		A4		B4		B4		A4	
Bankfull Discharge, Qbkf (cfs)	26.1	26.1	15.1	15.1	9.3	9.3	30.7	30.7	26.1	26.1	18.7	18.7
Bankfull Riffle XSEC Area, Abkf (sq ft)	5.9	5.9	4.3	4.3	3.5	3.5	6.7	6.7	5.9	5.9	3.8	3.8
Bankfull Mean Velocity, Vbkf (ft/s)	4.4	4.4	3.5	3.5	2.7	2.7	4.6	4.6	4.4	4.4	4.9	4.9
Bankfull Riffle Width, Wbkf (ft)	8.4	8.4	7.2	7.2	6.5	6.5	9.0	9.0	8.4	8.4	6.8	6.8
Bankfull Riffle Mean Depth, Dbkf (ft)	0.7	0.7	0.6	0.6	0.5	0.5	0.7	0.7	0.7	0.7	0.6	0.6
Width to Depth Ratio, W/D (ft/ft)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Width Floodprone Area, Wfpa (ft)	14.0	18.0	10.0	15.0	10.0	14.0	14.0	20.0	14.0	18.0	10.0	15.0
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	1.7	2.1	1.4	2.1	1.5	2.2	1.6	2.2	1.7	2.1	1.5	2.2
Riffle Max Depth @ bkf, Dmax (ft)	0.8	0.8	0.7	0.7	0.6	0.6	0.8	1.0	0.8	0.8	0.6	0.8
Riffle Max Depth Ratio, Dmax/Dbkf	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.1	1.1	1.1	1.4
Max Depth @ tob, Dmaxtob (ft)	0.8	0.8	0.7	0.7	0.6	0.6	0.8	1.0	0.8	0.8	0.6	0.8
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sinuosity, K	1.20	1.20	1.00	1.00	1.00	1.00	1.20	1.20	1.20	1.20	1.00	1.00
Valley Slope, Sval (ft/ft)	0.028	0.028	0.053	0.053	0.094	0.094	0.039	0.039	0.039	0.039	0.083	0.083
Channel Slope, Schan (ft/ft)	0.023	0.023	0.053	0.053	0.094	0.094	0.033	0.033	0.033	0.033	0.083	0.083
Slope Riffle, Srif (ft/ft)	0.026	0.042	0.058	0.095	0.103	0.169	0.036	0.059	0.036	0.059	0.091	0.149
Riffle Slope Ratio, Srif/Schan	1.1	1.8	1.1	1.8	1.1	1.8	1.1	1.8	1.1	1.8	1.1	1.8
Slope Pool, Spool (ft/ft)	0.0000	0.0093	0.0000	0.0212	0.0000	0.0375	0.0000	0.0131	0.0000	0.0131	0.0000	0.0332
Pool Slope Ratio, Spool/Schan	0.00	0.40	0.00	0.40	0.00	0.40	0.00	0.40	0.00	0.40	0.00	0.40
Pool Max Depth, Dmaxpool (ft)	1.4	2.5	1.2	2.1	1.1	1.9	1.5	2.6	1.4	2.5	1.1	2.0
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.0	3.5	2.0	3.5	2.0	3.5	2.0	3.5	2.0	3.5	2.0	3.5
Pool Width, Wpool (ft)	9.3	12.6	7.9	10.8	7.1	9.7	9.9	13.4	9.3	12.6	7.4	10.1
Pool Width Ratio, Wpool/Wbkf	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5
Pool Width/Depth Ratio	6.6	5.1	6.6	5.1	6.6	5.1	6.6	5.1	6.6	5.1	6.6	5.1
Pool Area, Apool, (ft/ft)	7.7	11.8	5.6	8.6	4.6	7.0	8.7	13.4	7.7	11.8	4.9	7.6
Pool Area Ratio, Apool/Abkf	1.3	2.0	1.3	2.0	1.3	2.0	1.3	2.0	1.3	2.0	1.3	2.0
Riffle Length, Lriffle (ft)	8.4	25.2	7.2	21.5	6.5	19.4	9.0	26.9	8.4	25.2	6.8	20.3
Riffle Length Ratio, Lriffle/Wbkf (ft)	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
Pool-Pool Spacing, Lps (ft)	12.6	42.1	10.8	35.9	9.7	32.4	13.4	44.8	12.6	42.1	10.1	33.8
Pool-Pool Spacing Ratio, Lps/Wbkf	1.5	5.0	1.5	5.0	1.5	5.0	1.5	5.0	1.5	5.0	1.5	5.0
d16 (mm)	12		15		12		8.5		8.5		5.2	
d35 (mm)	22		22		23		19		19		20	
d50 (mm)	31		29		30		32		32		31	
d84 (mm)	69		71		79		83		83		100	
d95 (mm)	92		90		270		130		130		160	

5.2.1.2 Dimension

Typical riffle and pool cross-sections are shown on the plan sheets in Appendix I for both streams. A bankfull W/D ratio of 12 was selected so that proper slopes could be created along the riffle banks and to help achieve the appropriate depth for sediment transport competency and capacity.

The ratio of low bank height to maximum bankfull depth (BHR) will be set to 1.0. In areas along the mainstem channel where bank height might exceed bankfull stage because of localized topography or a low stream bed elevation, minimal grading will be used to transition bankfull stage to the floodplain. Once flood water rises above the bankfull stage, bankfull benches allow the storm flow to spread out on the floodplain and reduce erosion-causing shear stress in the channel. In-stream structures will be used to provide bank protection and maintain pool cross-sections throughout the channel, where necessary. Typical cross-sections are shown on the plan sheets (Appendix I).

5.2.1.3 Pattern

As part of the restoration, the streams will be constructed with smoother pattern in areas, relocating the existing county road in the Right Fork of Upper Cane Creek and reclaiming the existing ATV/logging road along Commissary Branch. In most of the other areas, sinuosity will generally be decreased, hence reducing overall stream length throughout both streams. Rosgen B channels, typically do not have much lateral pattern, but maintain their sinuosity vertically by creating a more step-pool like system. Therefore, no design criteria for meander geometry are necessary. Plan views of the main channels are shown on the attached plan sheets (Appendix I) to demonstrate areas where sinuosity will change. The designed sinuosity ranges from 1.0 to 1.2 to maintain proper channel slopes.

5.2.1.4 Profile/Bedform

The stream restoration of both channels will include the construction of step pool sequences along the stream bed, using a combination of rock and log structures. The slopes for the riffles vary from 1.1 to 1.8 times the proposed channel slope. Pool slopes were designed using slope ratios of 0.0 to 0.4 times the design channel slope. The maximum pool depth (2.0 to 3.5 times the riffle mean depth) will be constructed from the head of one structure to the head of the next downstream structure along the profile.

5.3 Design Rationale – Hydrologic & Hydraulics

Sediment transport competency and capacity were qualified for the proposed typical cross-sections of the Right Fork of Upper Cane Creek and Commissary Branch. For the scope and level of stream channel enhancements proposed in this project, it was deemed that by using the dimensions, pattern, and profile outlined in the geomorphic design analysis, the proposed channel designs would be design for the appropriate flow capacity and sediment transport characteristics to maintain a stable channel form.

The type of enhancement may affect sediment transport on a localized basis at specific structures (e.g. substrate material size distribution will be altered at and adjacent to structures and pools), but this alteration is intended to provide an increase in preferred aquatic habitat.

5.4 Design Rationale – Biotic

The biotic functions of a stream system are highly influenced by the structural form of the stream channel itself. Aquatic organisms are suited to specific habitats, and with more diversity of habitats there is generally an increased diversity of aquatic organisms (i.e., a higher functional level). Natural, stable stream systems develop this diversity over time, through processes such as sediment transport, bed material sorting, organic matter collection, and vegetation growth. When stream systems become impaired, biotic functions are typically impaired as well as a result of excess sedimentation, loss of riparian vegetation, and channel disturbance.

In restored stream systems, newly constructed channels must be built in a way that ensures stability while also providing appropriate and diverse habitats. Stream channels are constructed to provide riffle, pool, and transition areas, with structural components to provide stability and habitat value. As the system matures over time, the restored stream will function more and more as a natural system, with biotic functions approaching those of reference sites.

5.4.1 In-Stream Structures

In-steam structures are used in restoration design to provide channel stability and promote certain habitat types. In-stream structures are necessary because newly constructed channels do not have dense riparian vegetation and roots that provide bank stability, nor do they exhibit a natural distribution of stream bed material that provides armoring and allows stable sediment transport processes. In-stream structures are used to provide stability to the system until these natural processes evolve to provide long-term stability and function to the system (see Table 5.3).

A variety of different structures will be installed including, but not limited to those described below. Specific locations of in-stream structures in each of the mitigation sites are presented on the attached plan sheets (Appendix I).

Table 5.3
Proposed In-Stream Structure Types and Locations

Structure Type	Location
Root Wads	Outer meander bends and other areas of concentrated shear stresses and flow velocities along banks.
Brush Mattresses	Outer meander bends, areas where bank sloping is constrained, and areas susceptible to high velocity flows.
Cross Vanes	Long riffles; tails of pools if used as a step; areas where the channel is overly wide; areas where stream gradient is steep and where grade control is needed.
Single Vanes and J-hooks	Outer meander bends; areas where flow direction changes abruptly; areas where pool habitat for fish species is desirable.
Cover Logs	Used in pools where habitat for fish species is desirable.
Root Wads	Outer meander bends and other areas of concentrated shear stresses and flow velocities along banks.
Log Weirs or steps	Riffles / steps of smaller streams.
Rock Step Pools	Riffles / steps of smaller streams.

5.4.1.1 Root Wads

Root wads are placed at the toe of the stream bank in the outside of meander bends and other areas of concentrated shear stresses along stream banks for the creation of habitat and for bank protection. Root wads include the root mass or root ball of a tree plus a portion of the trunk. They are used to armor a stream bank by deflecting stream flows away from the bank. In addition to stream bank protection, they provide structural support to the stream bank and habitat for fish and other aquatic animals. Banks underneath rootwads tend to become slightly undercut, forming an area of deep water, shade, and cover for a variety of fish species. Organic debris tends to collect on the root stems that reach out into the channel, providing a food source for numerous macroinvertebrate species. Root wads will be placed throughout the mitigation project.

5.4.1.2 Brush Mattress

Brush mattresses are placed on bank slopes for stream bank protection. Layers of live, woody cuttings are wired together and staked into the bank. The woody cuttings are then covered by a fine layer of soil. The plant materials quickly sprout and form a dense root mat across the treated area, securing the soil and reducing the potential for erosion. Within one to two years, a dense stand of vegetation can be established that, in addition to bank stability provides shade and a source of organic debris to the stream system. Deep root systems often develop along the waterline of the channel, offering another source of organic matter and a food source to certain macroinvertebrate species, as well as cover and ambush areas for fish species.

5.4.1.3 Cross Vanes

Cross vanes are used to provide grade control, keep the thalweg in the center of the channel, and protect the stream bank. A cross vane consists of two rock or log vanes joined by a center structure installed perpendicular to the direction of flow. This center structure sets the invert elevation of the stream bed. Cross vanes are typically installed at the tails of riffles or pools or within riffle sections to provide convergence and redirect flows away from streambanks. Cross vanes are also used where stream gradient becomes steeper, such as downstream end of a small tributary that flows into a large stream.

Scour pools form downstream of cross vanes, due to the increased flow velocity and gradient. Pool depth will depend on the configuration of the structure, the flow velocity and gradient, and the bed material of the stream. For many fish species, these pools form areas of refuge due to increased water depth, and prime feeding areas as food items are washed into the pool from the riffle or step directly upstream.

5.4.1.4 Single Vanes and J-Hooks

Vanes are most often located in meander bends just downstream of the point where the stream flow intercepts the bank at acute angles. Vanes may be constructed out of logs or rock boulders. The structures turn water away from the banks and re-direct flow energies toward the center of the channel. In addition to providing stability to streambanks, vanes also promote pool scour and provide structure within the pool habitat. J-hooks are vane structures that have two to three boulders placed in a hook shape at the upstream end of the vane. The boulders are placed with gaps between them to promote flow convergence through the rocks and increased scour of the downstream pool. Due to the increased scour depths and additional structure that is added to the pool, J-hooks are primarily used to enhance pool habitat for fish species. The boulders that cause flow convergence also create current breaks and holding areas along feeding lanes. The boulders also tend to trap leaf packs and small woody debris that are used as a food source for macroinvertebrate species.

5.4.1.5 Cover Logs

A cover log is placed in the outside of a meander bend to provide cover and enhanced habitat in the pool area. The log is buried into the outside bank of the meander bend; the opposite end extends through the deepest part of the pool and may be buried in the inside of the meander bend, in the bottom of the point bar. The placement of the cover log near the bottom of the bank slope on the outside of the bend encourages scour in the pool, provides cover and ambush locations for fish species, and provides additional shade. Cover logs are often used in conjunction with other structures, such as vanes and rootwads, to provide additional structure in the pool.

5.4.1.6 Log Weirs or Log Steps

A log weir or step consists of a header log and a footer log placed in the bed of the stream channel, perpendicular or at an angle to stream flow, depending on the size of the stream. The logs extend into the stream banks on both sides of the structure to prevent erosion and bypassing of the structure. The logs are installed flush with the channel bottom upstream of the log. The footer log is placed to the depth of scour expected, to prevent the structure from being undermined. This weir structure creates a “step”, or abrupt drop in water surface elevation, that serves the same functions as a natural step created from bedrock or a log that has fallen into the stream. The weir typically forms a very deep pool just downstream, due to the scour energy of the water dropping over the step. Weirs are typically installed with a maximum height of 3 to 6 inches so that fish passage is not impaired. Log weirs provide bedform diversity, maintain channel profile, and provide pool and cover habitat.

5.4.1.7 Rock Step Pools

A step pool consists of header rocks and footer rocks placed in the bed of the stream channel similar to a cross vane. This center structure sets the invert elevation of the stream bed. This rock structure creates a “step”, or abrupt drop in water surface elevation, that serves the same functions as a natural step created from bedrock or boulders that have fallen into the stream. The rock step pool typically forms a very deep pool just downstream, due to the scour energy of the water dropping over the step. Step pools are typically installed with a maximum height of 3 to 6 inches so that fish passage is not impaired. Like log weirs, rock step pools provide bedform diversity, maintain channel profile, and provide pool and cover habitat.

5.4.2 Vegetation

Native riparian and streamside vegetation will be established in the constructed buffer areas. Also, areas of invasive and introduced vegetation, such as autumn olive (Elaeagnus umbellate) and multiflora rose (Rosa multiflora), will be managed so that the newly-established native plants within the riparian buffer zones will not be threatened.

5.4.2.1 Stream Buffer Vegetation

Bare-root trees, live stakes, and permanent and temporary seeding will be planted within designated areas of the restoration. A minimum 25-foot buffer on each stream side will be established or enhanced upon along all restored stream reaches. In many areas, the natural buffer width will be in excess of 100 feet. In general, bare-root vegetation will be planted at a target density of 450 stems per acre. Planting of bare-root trees and live stakes will be conducted during the dormant season, with all trees installed prior to March 31. Depending on the seedings, plantings will occur between November and April (winter wheat, winter or perennial rye) at a rate of 130 pounds per acre or between April and August (brown top millet) at a rate of 40 pounds per acre.

Species selection for re-vegetation of the site will generally follow those suggested by Strausbaugh & Core (1978) and native species suggestions for West Virginia using the USDA’s Natural Resource Conservation Service Conservation Plant Database (2007). Selected species for hardwood re-vegetation are presented in Table 5.4. Tree species selected for stream restoration areas will be generally weak to tolerant of flooding. Weakly tolerant species are able to survive and grow in areas where the soil is saturated or flooded for relatively short periods of time. Moderately tolerant species are able to survive in soils that are saturated or flooded for several months during the growing season. Flood tolerant species are able to survive on sites in which the soil is saturated or flooded for extended periods during the growing season (WRP, 1997). Species selection may change due to availability of species at the time of planting.

Table 5.4
Bare-Root Trees Species Selected for Revegetation of the On-Site Mitigation Areas

Stream Banks (Live Stakes)			
Silky dogwood	*Cornus obliqua*	40%	65 to 100 stems per 1,000 SF
Silky willow	*Salix sericea*	40%	65 to 100 stems per 1,000 SF
Elderberry	*Sambucus canadensis*	20%	33 to 50 stems per 1,000 SF
Stream Riparian Buffer (Bare Root Trees)			
River birch	*Betula nigra*	30%	140 stems per acre
Tulip poplar	*Liriodendron tulipifera*	30%	140 stems per acre
Sycamore	*Platanus occidentalis*	20%	85 stems per acre
Southern red oak	*Quercus rubra*	20%	85 stems per acre
Alternate Species			
Silky Cornel	*Cornus amomum*		
Black Willow	*Salix nigra*		
Ninebark	*Physocarpus opulifolius*		
Elderberry	*Sambucus Canadensis*		

Observations will be made during construction of the site regarding the relative wetness of areas to be planted. Planting zones will be determined based on these observations, and planted species will be matched according to their wetness tolerance and the anticipated wetness of the planting area.

Once trees are transported to the site, they will be planted within two days. Soils across the site will be sufficiently disked and loosened prior to planting. Trees will be planted by manual labor using a dibble bar, mattock, planting bar, or other approved method. Planting holes for the trees will be sufficiently deep to allow the roots to spread out and down without "J-rooting." Soil will be loosely compacted around trees once they have been planted to avoid drying out.

Live stakes will be installed randomly two to three feet apart using triangular spacing or at a density of 160 to 360 stakes per 1,000 square feet along the stream banks between the toe of the stream bank and bankfull elevation. Site variations may require slightly different spacing. The live stake must be installed at a depth so that only 20% of the stake is exposed to sunlight, with a minimum of two lateral buds exposed.

A mixture is provided for streambank and stream riparian buffer areas. Mixtures will also include temporary seeding (winter wheat and winter rye or perennial rye) to allow for application with mechanical broadcast spreaders. Permanent seed mixtures will be applied to all disturbed areas of the project site. Table 5.5 lists the species, mixtures, and application rates which will be used. The permanent seed mixture specified for floodplain areas will be applied to all disturbed areas outside the banks of the restored stream channel and is intended to provide rapid growth of herbaceous ground cover and biological habitat value. The species provided are deep-rooted and have been shown to proliferate along restored stream channels, providing long-term stability.

Table 5.5
Permanent Seed Mixtures for Revegetation

Floodplain and Buffer Areas				
Virginia wildrye	*Elymus virginicus*	25%	2	FAC
Switchgrass	*Panicum virgatum*	25%	3	FAC+
Fox sedge	*Carex vulpinoidea*	25%	3	OBL
Redtop	*Agrostis alba*	25%	2	FAC
Restored Streambanks				
Virginia wildrye	*Elymus virginicus*	30%	12	FAC
Switchgrass	*Panicum virgatum*	30%	3	FAC+
Soft rush	*Juncus effusus*	20%	2	FACW+
Deertongue	*Dichathelium Clandestinum*	20%	12	FACW
Alternate Species				
Reed Canary Grass	*Phalaris arundinacea*			
Rice Cutgrass	*Leesia oryzoides*			
Wood Reed-Grass	*Cinna arundinacea*			

A mixture of the permanent seeding for restored streambanks and the temporary seeding will be applied to all disturbed areas of the site that are susceptible to erosion. These areas include constructed streambanks, access roads, side slopes, and spoil piles. A combination of both seeding types should be applied from November through April; and applied at a rate of 50 pounds per acre. Species selection may change due to availability of species at the time of planting.

5.4.2.2 Invasive Species Removal

To reduce the immediate threat and minimize the long-term potential of degradation, no identified invasive or introduced species will be planted in the mitigation sites. For instance, invasive or introduced species, such as but not limited to annual rye grass, timothy, weeping lovegrass, white clover, orchard grass, foxtail millet, autumn olive, European black alder, and red clover will not be used. Only plant materials native and indigenous to the region shall be used. Any natural invasion of such species detected during the monitoring period will be removed. Riparian vegetation will be monitored biannually the first year to ensure such species have not invaded the planted riparian zone. If invasive species are encountered, they will be immediately controlled by using either manual, chemical, or mechanical control efforts.

5.5 Design Rationale – Water Quality

Design considerations for the improvement of water quality in the restoration reaches focused on increased aeration, shading, and the addition of organic matter. These functional lifts are a result of a natural channel design which addresses stream dimension, pattern, and profile, placement of rock and wood in-stream structures and planting of riparian vegetation. These design options are described in Section 5.4. In addition to providing functional lifts the design will make alterations that reduce sediment both from upland and in-stream sources and enhance stream bank stability.

Water quality monitoring of impaired streams and the quantification of improvements through restoration requires substantial amounts of data collected over many years, both before and after restoration. Therefore, developing design criteria from site specific water quality monitoring is not practical. Instead, a thorough review of the literature was used as a guide to create a natural channel design that will ultimately improve water quality. The following discussion provides background information on the likely functional improvements associated with the natural channel design.

5.5.1 Dissolved Oxygen (DO)

Oxygen enters the water column of lakes, rivers and streams by at least two primary paths: by the production of aquatic autotrophs and by diffusion at the air-water interface. The autotrophic supply of oxygen is usually minimal in the small rivers and streams on which most stream restoration projects are done. A lotic or flowing water system primarily obtains oxygen at its surface and as the surface is agitated by water falling down slope. Any structure within the channel which breaks the water surface and causes increased velocity and turbulence will cause oxygen that is in the air to diffuse into the water. This water borne oxygen is referred to as dissolved oxygen (DO). Turbulence increases the diffusion of oxygen into the water column up to the point where the water column is saturated or in equilibrium with that in the air. Under significant turbulence the water column can become super-saturated but this is usually short lived as oxygen diffuses back into the atmosphere.

Stream restoration designs usually incorporate various types of structures (Section 5.4.1) for the variety of benefits they can provide. These benefits include bank stabilization, grade control, channel narrowing, and habitat creation. Most of these structures also provide the added benefit of increasing oxygenation of the stream. For example, “random” boulder clusters or structures that are created from clusters of boulders cause turbulence of flow resulting in eddies or vortices downstream of the boulder (Fischenich and Seal, 1999). This turbulent flow pattern causes a greater interface surface area of air and water, and oxygen levels can increase to equilibrium. Because all stream restoration structures that extend above the water surface cause this type action they contribute to increasing the oxygen supply of the stream.

Aquatic species have adapted to the specific environments in which they are found. Part of adapting to an environment is evolving the ability to extract needed oxygen from that environment. Fish species have adapted to a range of environmental oxygen availabilities. Trout and salmon require oxygen concentrations that are at or slightly below saturation, while other fish families like catfish, sunfish and some minnows have adapted to survive in waters with an oxygen concentration below 50% of saturation (Calhoun, 1966; Moss and Scott, 1961). This is accomplished by having differing types of hemoglobin that varies in its affinity for oxygen (Moyle and Cech, 1982).

The ability of fish to function normally depends on their environments supplying the levels of DO to which they are adapted. Due to their importance in major fisheries, salmonids have been intensively studied and this data illustrates the importance of DO to fish. The swimming performance of migrating salmon drops as DO drops below air-saturation levels (Bjornn and Reiser, 1991). Areas of low DO will also be avoided by migrating salmon. Hallock et al. (1970) observed that adult salmon ceased to migrate as DO fell below 4.5 mg/L and did not resume until DO was greater than 5 mg/L. Minimum DO for spawning salmon was found to be 80% of saturation and not less than 5 mg/L.

The behavior of warm-water fish species is also affected at certain critical DO levels. Dahlberg (1968) showed that largemouth bass, Micropterus salmoides, had a greatly reduced swimming speed at oxygen concentrations below 6 mg/L. Nine species of aquatic insects were studied to see what their tolerance for low DO levels would be (Nebeker, 1972). As in fish, a wide range of acceptable DO levels was found. One species of midge could survive DO concentrations down to 0.6 mg/L, while a mayfly could only survive conditions slightly below saturation at 18.5 C. Like fish, aquatic insects have adapted to a specific range of DO.

Trout and salmon are among the most sensitive species to sedimentation because of how it influences the availability of DO to their eggs. Salmonids deposit their eggs in gravel areas called redds. They will only choose gravel that is clean and relatively free of fine sediment. The eggs hatch in the redd and hatchlings remain in the interstitial spaces of the gravel until they develop to a point where they become free swimming. While they are in the gravel they are very vulnerable to sediment or organic material which can cover the gravel and reduce or eliminate the movement of oxygenated water through the gravel. There is an inverse relationship between DO and the percentage of fines in stream substrates (Reiser and White, 1981). Water velocity directly influences the fines found in substrates and Coble (1961) observed that when water velocity is low, DO will be low, and when water velocity is high, DO will be high. When eggs experience low intergravel DO their development can be altered or they can die. Chum salmon were delayed in hatching and showed an increase incidence of morphological anomalies under low DO concentrations (Alderdice et al., 1958).

Structures used in stream restoration usually cause an increase in DO concentrations as they increase turbulent flow toward the center of the channel. Structures that concentrate flow to a central area or point will cause scour on the stream bottom and sorting of bed material. This action results in well-oxygenated deep water habitat and a glide out of the pool with well sorted gravels that contain very little fine material. The increased water velocity coming out of the scour hole will cause a good flow of well oxygenated water through the gravel. This is the type of habitat that salmonids and other stream fishes will choose for spawning. Stream restoration structures result in turbulent flows directed toward the center of the channel, which improves physical habitat and increases the level of dissolved oxygen in the water column.

5.5.2 Temperature

Water temperature is a primary factor determining the fish population inhabiting a stream. Brett (1971) considered temperature to be the master abiotic variable for fishes. Fishery managers have long recognized the importance of temperature to fish distribution and have separated lotic systems into warm-water streams and cold-water streams. Warm-water streams are those where temperatures exceed 24°C to 26°C for extended periods of time and cold-water streams are those that rarely exceed this temperature range (Moyle and Cech, 1982). Trout and sculpin would normally be expected in the cold-water, higher elevation, 1st to 3rd order reaches. As the stream increases in order the diversity of fish and other aquatic organisms' increases, it becomes a cool, and then warm-water system and a typical fish community would be composed of sunfish, catfish, and minnows (Vannote et al, 1980).

While not presented above in the discussion of DO, temperature is a primary variable in determining how much oxygen will diffuse into the water column. Oxygen concentration decreases with increasing temperature (Wetzel, 1983). Activities that impact the riparian vegetation along a stream and cause a warming of the stream also cause a decrease in the oxygen carrying capacity of the stream.

Because fish are cold-blooded they are generally the same temperature as the water they reside in. Unsuitable temperatures can cause disease outbreaks, can alter normal migration and spawning behavior and can accelerate or retard maturation (Bjornn and Reiser 1991). Salmonids, which require low water temperatures, primarily have suitable habitat defined by the limiting factor of stream temperature. (Magnuson et al., 1979). Salmonids have been found to delay their upstream migration when natal streams were too warm (Monan 1975). The range of trout in the southern Appalachian Mountains is presently limited by temperature. In a warming global atmosphere the range of trout in the southeast is likely to shrink. Flebbe et al. (2006) used two global circulation models to estimate that trout habitat in the southeast may shrink in area from 53% to 97% given a 2.5°C to 5.5°C increase in global temperature, respectively. Understanding the range of temperatures that fish species can survive has been a major area of study since the 1800s. Beitinger et al. (2000) conducted an extensive review of the literature on temperature tolerance in fishes. While much of the research on how stream temperature affects resident organisms has been directed to fish, all aquatic organisms depend on the proper stream temperature to maintain their life cycles and metabolism. An example of how dependent other aquatic species are on specific temperatures can be seen in a study of sixty-one macrobenthic species. They had a reduced body size at a given developmental stage when reared at water temperatures that were higher than normal but not at a level high enough to cause obvious stress (Atkinson, 1995).

Stream temperature can be altered by a number of causative agents. Most often stream restoration projects are successful at improving altered temperature regimes of streams that have had their riparian vegetation removed or greatly reduced. Diverse riparian vegetation is planted to reestablish a native riparian plant community and the area is protected from future impacts. In time the riparian vegetation will shade the stream and limit heating of the water. The vegetated riparian buffer will also reduce rapid cooling at night by insulating the channel area. Clemmons (2000) found that when recording thermometers were set approximately 25 feet apart, one in the shade in an open field and the other inside a well vegetated riparian zone, that air temperature differences due to the riparian vegetation where significant. Air temperature during the hottest part of the day averaged 3.7°C hotter in the field over a 7 day period. On one sunny day the field air temperature was 5.4°C hotter and had a 24-hour minimum to maximum range of 15.3°C. At night the buffer did not get as cool and averaged 0.4°C warmer. Trees that provided shade to several headwater streams in Oregon were killed by forest fire, reducing shade from a pre-fire coverage of >90% to a post-fire coverage of 30%. This resulted in water temperature increases that ranged from 3.3°C to 10.0°C (Amaranthus et al., 1989). These data show the importance of riparian vegetation for maintaining cool stream water temperatures.

Riparian vegetation also plays an important role in regulating soil moisture, temperature and soil loss due to freeze-thaw cycles (Wynn and Mostaghimi, 2006). Trees provide the best protection against erosion of soils that are susceptible to desiccation, and herbaceous vegetation better protects silty soils that are prone to erosion due to the freeze-thaw cycle. Riparian improvements through cattle exclusion, stream bank sloping and structural bank protection were shown to reduce water temperatures on a Wisconsin stream to the point that brown trout began spawning. However, in watersheds where only limited riparian work was done there was no improvement to water temperatures (Wang et al. 2002). A comparison between streams that had their riparian zones protected by exclusionary fencing 10 to 20 years prior to the study and streams that had not been protected demonstrated the benefits of riparian vegetation. Late summer water temperatures within the exclosure areas were cooler and within acceptable range for resident trout, while areas not protected had temperatures that were potentially detrimental. Exclosure areas also had a more stable stream morphology and greater quantities of large woody debris (Opperman and Merenlender 2004).

Stream restoration plans should include planting and protection of stream riparian areas. This will provide the shade that protects the thermal regime of the stream. Structures that are installed also enhance habitat and help maintain cool water by creating deep pools and overhead cover. Mesick (1995) found that after stream restoration, brown trout survival and growth were positively correlated with the amount of pool habitat, water depth, and streambed complexity particularly when summer water temperatures were high.

5.5.3 Organic Matter

Energy is made available to stream organisms through 2 primary sources: either photosynthesis by aquatic plants (autochthonous sources) or decomposition of organic material deposited in the stream (allochthonous sources) (Murphy and Meehan, 1991). In small 1st to 3rd order streams the primary source of energy is an allochthonous source. Fisher and Likens (1973) found that organic material from the adjacent forest provided 98% of the organic matter of Bear Brook in New Hampshire. Deciduous trees provide the greatest input of organic matter to streams. The total biomass of trees is several orders of magnitude greater than herbaceous or shrub stands; however, the foliar biomass of trees is 5 to 20 times greater (Gregory et al., 1991). Conifers have a greater foliar biomass but since they lose only a fraction of that in a year it does not contribute the biomass that deciduous trees do and on a seasonal pattern. There is a shift from allochthonous to autochthonous production and an accompanying shift in the organisms that exploit those energy sources as a stream moves higher in order and lower in elevation. (Vannote et al, 1980).

Stream restoration projects and the structures that are installed during those projects, improve the long-term ability of the stream riparian zone to create organic matter and for the streams aquatic organisms to utilize it. This is accomplished by reestablishing a diverse riparian plant community that will provide leaf litter and woody debris. Structural improvements enhance the streams ability to retain the organic material within the stream so that micro and macrobenthic organisms can break it down and use the liberated energy for growth. Structures such as rootwads provide complex root systems installed below the water surface which function to capture organic material (Sylte and Fischenich, 2000). The high surface area of a rootwad also provides benthic organisms extensive colonizing space on which they can process the organic material. Vane type structures slow the water down along the bank causing a depositional area where organic material accumulates and can be utilized by organisms.

Muotka and Laasonen (2002) examined the ability of restored streams in Finland to retain leaf litter as compared to unrestored streams. They found that restoration increased substrate heterogeneity and that retention efficiency was higher than in the control channelized streams. Retention was not as good as in natural streams which had greater densities of moss that enhanced retention. Lepori et al. (2005) compared channelized streams that were restored using boulders and woody debris with unrestored channelized streams and unimpacted reference stream sites. They found that coarse particulate organic matter retentiveness was most closely related to the density of boulders and submerged woody debris. Restored reaches were on average twice as retentive as the channelized control streams and were even significantly more retentive than reference reaches. They felt that “restoration by replacement of boulders and woody debris can successfully reverse impacts of channelization and thus contribute to the efficient ecological functioning of impacted streams.”

Wallace et al. (1995) performed an experiment by adding logs to the downstream riffle of three paired riffles to evaluate the biotic and abiotic response. Where logs were added stream depth increased, velocity decreased, fine bed material was deposited and both coarse and fine particulate organic matter increased dramatically. This had an immediate and significant impact on the invertebrate community structure as it shifted from scrapers and filterers too collectors and predators. When leaf litter decomposition was used to evaluate post-restoration recovery of stream function on a Kentucky stream, it was found that within the 9-month study period mean litter residence time of the restored reach was approximately equal to the upstream control reach (Gentry, 2005).

Shields and Knight (2003) assessed the effects of installing stone structures and planting the riparian area along a Mississippi stream. Ten years after work was completed they found improvements to both habitat and the fish communities. Mean water depth was twice that of untreated reaches. Woody riparian vegetation more than doubled and in-channel LWD increased by an order of magnitude. The fish population changed from numerous, small fish (cyprinids) to fewer large fish (centrarchids) which could support a fishery. Large woody debris (LWD) was found to be the preferred habitat of trout in North Carolina wilderness streams (Flebbe and Dolloff, 1995), and Roni and Quinn (2001) found that LWD placement in 30 western streams lead to increased densities of salmon and trout during certain times of the year.

Some organic nutrient inputs can be detrimental to stream ecosystems when they are artificial and excessive. Riparian vegetation can significantly benefit the stream by intercepting the movement of overland or subsurface nutrients. The demand for nutrients by riparian vegetation can greatly reduce dissolved nutrient loads moving down slope. Riparian forests in Maryland were found to remove three-quarters of the dissolved nitrate moving off of croplands and into an adjoining river (Peterjohn and Carrell, 1984). Lowrance et al. (1984) found that the riparian forest of a Georgia coastal plain stream was an excellent nutrient sink and buffered the nutrient discharge moving off of surrounding agricultural fields.

Establishing a riparian forest along restored streams is essential if the aquatic community is going to have an adequate source of organic material to support the food chain. Beyond this vital function, riparian vegetation also captures soil that is moving down slope to the stream. Riparian vegetation is a critical component to a properly functioning lotic ecosystem. Large woody debris is an important component of natural streams and is utilized extensively in stream restoration projects, both as log structures and as rootwads. Boulder structures are also a natural component of some streams and should be used where appropriate to enhance habitat and improve retention of organic material. These studies indicate that stream restoration structures, in concert with reestablishing the riparian forest that will provide organic material, can be successful at restoring a functioning stream ecosystem.

5.5.4 Sediment

Stream restoration projects are probably most often instigated to address obvious and chronic erosion and sedimentation problems. Geomorphic modifications and the placement of structures are often guided by the need to alter existing forces and situations that are causing stream banks to become unstable. Sediment is recognized by most if not all states as the worst pollutant of our nation's waterways. Waters (1995) in his extensive review of the literature dealing with sediment in streams states that "After a half-century of the most rigorous research, it is now apparent that fine sediment, originating in a broad array of human activities, overwhelmingly constitutes one of the major environmental factors—perhaps the principal factor—in the degradation of stream fisheries."

Sediment is an insidious pollutant because it is natural for streams to carry a certain amount of sediment. In fact a stream bed that is heterogeneous in terms of sediment sizes will support the greatest diversity of insects (Minshall, 1984). However, when the "normal" amount or size of sediment changes it begins to degrade the aquatic environment. Sediment is considered a pollutant when the quantity and quality is unnatural. When this occurs the impact on all aquatic organisms in a stream system can be significant.

Three streams in the Piedmont ecoregion of North Carolina that differed in terms of land use within their drainages, being either forested, agricultural or urbanized, were compared (Lenat and Crawford, 1994). The forested stream differed from the other two streams which had similar water quality. Suspended sediment yield was greatest for the urban stream and least for the forested stream. Storm flows showed a similar pattern but suspended sediment concentrations were highest from the agricultural stream on low to moderate flows. Invertebrate sampling indicated that the agricultural stream was at a moderate stress level and the urban site had severe stress. Lemly (1982) examined the effects of inorganic sediment and nutrient enrichment on the benthic insect community of a southern Appalachian trout stream. Pollutants entered the stream at different points allowing an assessment of how sediment alone and sediment in association with nutrient enrichment impacted insect communities. Diversity and biomass of certain species were significantly reduced in the polluted zones. Sediment filling interstitial spaces and disrupting feeding was considered to be the primary factor affecting filter feeding taxa. Inorganic sediment directly affected stream insects by particles accumulating on body surfaces and respiratory structures. In the zone of nutrient enrichment, particle laden insects were also observed to have growths of filamentous bacteria. Thus, sediment and nutrient enrichment operated synergistically to eliminate a significantly greater number of stream insect taxa. Richards et al. (1993) sampled macroinvertebrate community composition in streams of a large Michigan watershed. Benthic communities of streams where agriculture was a primary land use were the most different from other streams. Substrate characteristics were the most important variable for explaining variation in benthic communities. Significant correlations were observed between substrate quality and the total numbers of Ephemeropteran, Plecopteran, and Trichopteran (EPT) taxa. This supports using EPT taxa as an indicator of stream quality.

There is a wide body of information on the effects of sediment on fish, particularly cold water species. Waters (1995) provides an extensive review of these studies. In the DO discussion above the impact of sediment on salmonids is explained relative to how it limits transfer of DO to incubating eggs. Cederholm et al. (1980) examined the effects of siltation from logging roads on salmonid spawning success. They found that the survival of eggs to emergence was inversely correlated with the proportion of fines when the percentage of fines exceeds the natural level of 10 percent. With every 1 percent increase in fines there is a rapid decline in survival to emergence. Binns (2004) analyzed wild trout abundance, biomass and habitat prior to and after 30 habitat enhancement projects by the state of Wyoming. Trout biomass and abundance increased for most of the projects. Cover for trout and pool depth significantly increased and erosion from stream banks significantly decreased. The influence of sediment on fish reproductive success varies with the reproductive guild of the fish (Balon, 1975). Species that depend on clean stony substrates to deposit their eggs in or on, suffer the greatest impacts and species that have floating eggs or that guard and clean their eggs will have the least impact. Sediment can also bury fish cover and habitat. Branson and Batch (1972) reported that some fish species were eliminated from a Kentucky stream by mining activities that deposited clay sediments on the bottom of the stream to a depth of 2 to 6 inches.

Even amphibian populations have been shown to be affected by excessive sediment moving in a stream. Corn and Bury (1989) studied one species of frog and 3 species of salamanders in 43 streams in Oregon. Twenty-three were in forested watersheds and twenty were in watersheds that had been cut within 14 to 40 years of the study. Streams that were in the cut areas had greater deposits of sediment within the stream and had a smaller substrate particle size. All four amphibian species had higher densities and biomass in the uncut watersheds. Investigators attributed the difference to loss of interstitial spaces that the larvae of these species need for proper development.

Restoring a stream to its proper dimension, pattern and profile will create a channel that moves water and sediment through the reach without causing aggradation or degradation. The purpose of stream restoration using a natural channel design approach is to evaluate what geomorphology the channel needs to avoid having erosion or depositional problems. Common adjustments that restore stream stability might include developing a meandering pattern to increase stream length and reduce stream slope, adjusting the cross-section to provide good habitat while moving sediment through the reach, and installation of stream structures that protect eroding stream banks by reducing near bank shear stress..

The most common reason that stream banks become unstable and cause sedimentation of the stream is that the land adjoining the stream has been used in such a way that riparian woody vegetation is significantly diminished or eliminated. This inevitably results in unstable stream banks that erode at the bank toe and when erosion has caused sufficient loss of support the bank slumps. To mitigate this problem trees are planted to reestablish a stable stream bank. Wynn et al. (2004) found that at depths greater than 30 cm forested riparian sites had significantly greater fine and small root length density than did herbaceous sites. Since the greatest shear stress is at the toe of the stream bank and since erosion at the toe most often causes bank failures, trees should be planted along banks to protect the toe. Trees will produce a root system that will grow to a depth that allows the fine and small roots to bind with the soils, increasing the soil critical shear stress (Gray and Leiser, 1982). Dunaway et al. (1994) found that the erosion rate was inversely proportional to root volume. So restoration projects that enhance or reestablish woody vegetation along stream banks significantly reduce the likelihood of bank failure and sedimentation of the stream.

As demonstrated by this information, sediment significantly impacts the ability of aquatic organisms to survive and grow in a lotic environment. It could be said that stream restoration is completely about understanding and manipulating erosional and depositional processes, using abiotic and biotic structure. Successful restoration will result in a stream carrying a natural sediment load that promotes species diversity and health.

6.0 PERFORMANCE STANDARDS AND MONITORING

Channel stability, stream functions, biotic assessments, and vegetation survival will be monitored as part of this mitigation project (Section 9.0). Monitoring and success will be measured on each mitigation reach that involves stream restoration or enhancement work (Table 6.1). Each of the components described below will be monitored at the mitigation reaches, with the exception of biotic monitoring and assessment in the ephemeral reaches (Table 6.1).

Table 6.1
Success Criteria and Monitoring Actions

Type/Category	Criteria	Year 1	Year 2	Year 3	Year 4	Final Value (after 5 years)
Geomorphology	BEHI (Max)	High (Below 35)		Moderate (Below 30)		Moderate (Below 25)
	Sediment Production From Banks (bankpins or crosssections)	Report annual sediment production from banks	Report annual sediment production from banks	Report annual sediment production from banks	Report annual sediment production from banks	Mean sediment production from banks less than 0.5 feet/year over years 3-5
	Stable banks and channel (photos)*	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually	Assessed visually for instability. Photograph documentation annually
Hydrology	Crest gage or observation	Report greater than bankfull flows	Report greater than bankfull flows	Report greater than bankfull flows	Report greater than bankfull flows	Greater than bankfull flows reached active floodplain stage during monitoring period
Vegetation	Min % Trees Native	50%	50%	50%	60%	75%
	Max % Trees Non-native	50%	50%	50%	40%	25%
	Max.% Trees Invasive	40%	40%	25%	25%	10%
	Max % Invasive plants (herbaceous or woody)	40%	40%	25%	25%	25%
	Min. Native Stem Density per acre	150	150	150	300	300
	Maximum Percent any one tree Species	50%	50%	50%	35%	25%
	Species List (Scientific & Common Name, Wetland Status Indicator, Native vs. Non-Native vs. Invasive)	Yes	Yes	Yes	Yes	Yes

Type/Category	Criteria	Year 1	Year 2	Year 3	Year 4	Final Value (after 5 years)
Habitat	RBP	Report RBP score		Report RBP score		Mean RBP score "excellent" by year 5**
Biotic*	USEPA RBP (benthics)	Sample year 1		Sample year 3		Sample year 5 *Equivalent or higher metrics and values than a compared reach that has not been restored*

*RBP biotic metric will not be used to determine project success/failure, but goals have been set for year 5

**Minimum score to qualify as "Excellent" varies by bioregion

6.1 Photograph Documentation

Photographs will be used annually to evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, and effectiveness of erosion control measures subjectively. Lateral photos should not indicate excessive erosion or continuing degradation of the banks. A series of photos over time should indicate successive maturation of riparian vegetation.

Reference stations will be photographed before construction and continued for a minimum of five years following construction or until such mitigation is deemed successful. Reference photos will be taken once a year. Photographs will be taken from a height of approximately five to six feet. Permanent markers will be established to ensure that the same locations (and view directions) on the site are documented in each monitoring period.

The water line will be located in the lower edge of the frame, and as much of the bank as possible will be included in each photo. Photographers should make an effort to consistently maintain the same area in each photo over time.

6.2 Geomorphology & Hydrology Success Criteria

Geomorphic monitoring and success criteria of restored and enhanced stream reaches will be conducted for a minimum of five years to evaluate the effectiveness of the mitigation practices. The related success criteria are described below for each monitored parameter.

6.2.1 Bankfull Events

The occurrence of bankfull events within the monitoring period will be documented by the use of water level gages and photographs. A crest gage will be installed along each mitigation reach and will record the stream water level. Photographs will be used in addition to the water level gage to document the occurrence of debris lines and sediment deposition on the floodplain during monitoring site visits.

Two bankfull flow events will be documented within the five year monitoring period. The purpose of monitoring bankfull events is to document that out-of-bank flows and an active floodplain have been restored as part of the mitigation work.

6.2.2 BEHI

Bank erosion hazard index (BEHI) scores will be collected in each of the restored and enhanced channels. BEHI scores were collected prior to initiation of mitigation and those collected after mitigation. The final success criteria will be achieved by demonstrating an increase in BEHI scores from existing condition values at the end of the five year monitoring period (Table 7.2). If scores are not met, remedial actions may be necessary (Table 6.1).

6.3 Vegetation Success Criteria

While measuring species density is the current accepted methodology for evaluating vegetation success on restoration projects, species density alone may be inadequate for assessing plant community health. For this reason, the vegetation monitoring plan will incorporate the evaluation of additional plant community indices to assess overall vegetative success.

The measure of vegetative success for the site will be examining minimum and maximum percentages of native and invasive tree species throughout the site, density per acre, total percentage of any one species, and examining total species present. Specific success criteria of each of these criteria are outlined in Table 6.1. For instance, it is projected that he survival of at least 300 stems (tree and shrub stems) five years after planting, as well as, throughout the monitoring period is required to determine success. All trees and shrubs will be selected based upon their hydrologic and edaphic tolerances, wildlife food and cover value and will be native to the area.

6.4 Habitat Success Criteria

Specific and measurable success criteria for habitat will include comparison of the average habitat assessment value (HAV) collected prior to initiation of mitigation and those collected after mitigation. The final success criteria will be achieved by demonstrating an increase in HAV scores from existing condition values at the end of the five year monitoring period (Table 7.2). If scores are not met, remedial actions may be necessary (Table 6.1).

6.5 Biotic Success Criteria

6.5.1 Benthic Macroinvertebrates & Water Quality

Biotic assessments were conducted prior to the initiation of mitigation. After construction, biotic monitoring will be conducted during the spring (February 15 thru April 15) sampling season during year one, year three, and year five following construction (USEPA, 2000). As recommended in the USEPA guidance (2000), baseline water chemistry parameters will be collected with each biotic sampling event. Field pH, conductivity, dissolved oxygen, temperature, and measured discharge will also be collected during the benthic macroinvertebrate monitoring. A detailed methodology for each of the monitored biotics is provided in Section 2.0 of this report.

Specific and measurable success criteria for benthic macroinvertebrates will include comparison of the benthic macroinvertebrate metrics and values at the restored stations and un-restored stations. The final success criteria will be the achievement of at equal or greater than the existing conditions at the end of the five year monitoring period.

6.6 Reporting Methods

An as-built survey report documenting the stream restoration or enhancement efforts will be developed within 60 days of the completion of planting on the restored sites. The report will include all information required by the USACE, Regulatory Guidance Letter dated August 3, 2006 (USACE, 2006), including elevations, photographs, monitoring stations, sampling plot locations, a description of initial species composition by community type, and a summary of the biotic monitoring results. The report will include a list of the species planted and the associated densities. The monitoring program will be implemented to document system development and progress toward achieving the success criteria referenced in the previous sections. Stream morphology, hydrology, and vegetation, will be assessed to determine the success of the mitigation. The monitoring program will be undertaken for a minimum of five years, or until the final success criteria are achieved (Section 8.1). Monitoring reports will be prepared each year of monitoring and submitted to the USACE by December 31. The monitoring reports will include:

- A detailed narrative summarizing the condition of the mitigation site and all regular maintenance activities;
- As-built topographic maps showing location of monitoring stations, vegetation sampling plots, permanent photo points, and location of transects;
- Photographs showing views of the mitigation site taken from fixed-point stations;
- Hydrologic information;
- Vegetative data;
- Identification of any invasion by undesirable plant species, including quantification of the extent of invasion of undesirable plants by either stem counts, percent cover, or area, whichever is appropriate;
- Biotic data;
- A description of any damage done by animals or vandalism;
- Wildlife observations; and
- Reference hydrology and stream data.

7.0 SITE PROTECTION

Due to the relocation of a county road along the Right Fork of Upper Cane Creek, both a road easement and a stream easement were developed with the current landowners for the project. The current land owners at the proposed mitigation sites include six (6) different private landowners listed below. A 50-foot riparian buffer (25-feeet on each streamside) will be provided along the stream mitigation areas (Appendix E). The road easement will be a varying easement based on the construction limits. The actual easement along the new road alignment will vary between 25 feet to 100 feet in width (Appendix E). Copies of both the stream and road easement documents are included in Appendix E. The easement documents will be filed in the Menifee County courthouse. Contact information for the landowners is provided below.

Chip Culton
Dale Gough
Richard Shadwick
Randy Phipps
Dennis Phipps
Ron Lutrell

228 Murphy Lane
Nicholasville, KY 40356
(859) 229-0515

8.0 CONTINGENCY PLAN

A post-mitigation monitoring period has been discussed in Section 9.0 of this plan. In the event that successful mitigation of jurisdictional waters cannot be achieved, KY Fish & Wildlife proposes to conduct repair, corrective, and/or maintenance throughout the project site during the five year monitoring period. Structures, stream banks, and vegetation will be visually monitoring each year. If any failures are noticed, KY Fish & Wildlife will implement a plan to repair, correct, or maintain.

8.1 Maintenance Issues

Maintenance requirements vary from site to site and are generally driven by the following conditions:

- Projects without established, woody floodplain vegetation are more susceptible to erosion from floods than those with a mature, hardwood forest.
- Projects with sandy, non-cohesive soils are more prone to short-term bank erosion than cohesive soils or soils with high gravel and cobble content.
- Alluvial valley channels with wide floodplains are less vulnerable than confined channels.
- Wet weather during construction can make accurate channel and floodplain excavations difficult.
- Extreme and/or frequent flooding can cause floodplain and channel erosion.
- Extreme hot, cold, wet, or dry weather during and after construction can limit vegetation growth, particularly temporary and permanent seed.
- The presence and aggressiveness of invasive species can affect the extent to which a native buffer can be established.

Maintenance issues and recommended remediation measures will be detailed and documented in the as-built and monitoring reports. The conditions listed above and any other factors that may have necessitated maintenance will be discussed.

9.0 ADAPTIVE MANAGEMENT

With the application of adaptive management, this mitigation plan is intended to survive well beyond the visible planning horizon, remaining viable and vital to any future planning efforts throughout the watershed.

The concept of adaptive management acknowledges the dynamic nature of natural systems and the changing state of knowledge and developing management strategies. Adaptive management involves acknowledging new information and making objective judgments regarding whether to change strategies to better achieve management objectives. If new information indicates an alternative strategy is effective, the plan should provide the flexibility and allow the latitude to pursue it. It is very difficult to predict what adjustments might be necessary in the future.

Additions or changes to this mitigation plan will occur only with the approval of the regulatory agencies, aside from specific structure locations or slight field modifications during construction, of which will be documented and professionally certified in the final as-built surveys. In order to keep the plan document current and relevant, the following items will be reviewed on a regular basis:

- All resource permitting requirements will be reviewed and revised, as appropriate.
- Monitoring data from on-going programs will be reviewed to determine whether plan revisions or adaptive management are warranted.
- Other newly reported data coming to KY Fish & Wildlife's attention will be evaluated and a determination made regarding whether it warrants a revision to the plan.
- Specific goals will be periodically reassessed to determine if they have been met and if prioritization or tasks shall be changed based on the outcome of the monitoring and maintenance.

10.0 FINANCIAL ASSURANCES

KY Fish & Wildlife is financially secure with regards to its ability to complete all required jurisdictional waters restoration activities, including all necessary post-mitigation maintenance and monitoring. KDFWR is financially secure to provide remedial actions if needed. The property owners have the resources to manage and protect the site in perpetuity.

11.0 DISCLAIMER

This project was assembled at the client's request by Michael Baker Jr., Inc., using data and information provided by KY Fish & Wildlife. The scope of this study was mutually devised by Michael Baker Jr., Inc., and the client and it is limited to the specific project, location, and time period described herein.

Michael Baker Jr., Inc., assumes no responsibility for information provided or developed by others or for documenting conditions detectable with methods or techniques not specified in the work scope. Michael Baker Jr., Inc. has reviewed the information provided by others and found it to be credible for the purpose of this report.

This report is intended for the use of the designated client within a reasonable period of time from its issuance. Michael Baker Jr., Inc., also has not independently verified information furnished by other parties included in this report and therefore cannot warrant the accuracy, completeness, legality, reliability, or efficacy of such information. However, Michael Baker Jr., Inc., has deemed this information to be credible at the time of issuance of this report and therefore, its use is considered to be judicious. Conclusions derived from this report are subject to revision if unverified data is demonstrated after issuance of this report to be incomplete or inaccurate, there are modifications to the data, or there emerges significant new data. Unauthorized or unintended use of this report or the information contained herein shall indemnify Michael Baker Jr., Inc. from any and all injury, damage, and liability arising from such use. This disclaimer applies to both partial and aggregate uses of this report.

12.0 REFERENCES

Adams, R. K., James A. Spotila . 2005. The form and function of headwater streams based on field and modeling investigations in the southern Appalachian Mountains. Earth Surface Processes and Landforms. Volume 30 Issue 12, Pages 1521 – 1546 28 Oct 2005

Alderdice, D. F., W. P. Wickett, and J. R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal of the Fisheries Research Board of Canada. 35:69-75.

Amaranthus, M., H. Jubas and D. Arthur. 1989. Stream Shading, Summer Streamflow and Maximum Water Temperature following Intense Wildfire in Headwater Streams. USDA Forest Service. Gen. Tech. Rep. PSW-109. pp. 75-78.

Andrews, E. D. 1983. Entrainment of gravel from naturally sorted river bed material. *Geological Society of America Bulletin* 94: 1225-1231.

Balon, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. Journal of the Fisheries Research Board of Canada 32:821-864.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. EPA 841-B-99-002. U. S. Environmental Protection Agency, Office of Water, Washington, D.C.

Bartsch, A.F. and Ingram, W.M. 1966. Biological analysis of water pollution in North America. Verh. Int. Verein. Limnol. 16: 786-800.

Beitinger, T. L., W. A. Bennett, and R. W. McCauley. 2000. Temperature tolerances of North American freshwater fishes exposed to dynamic changes in temperature. Environmental Biology of Fishes 58:237-275.

Binns, N. A. 2004. Effectiveness of Habitat Manipulation of Wild Salmonids in Wyoming Streams. North American Journal of Fisheries Management 24:911-921.

Binns, N. A. and F. M. Eiserman. 1979. Quantification of Fluvial Trout Habitat in Wyoming. Transactions of the American Fisheries Society 1979;108:215–228

Bjornn, T. C. and D. W. Reiser 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication. 19:83-138.

Branson, B. A., and D. L. Batch. 1972. Effects of strip mining on small-stream fishes in east-central Kentucky. Proceedings of the Biological Society of Washington 84:507-518.

Brett, J. R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (Oncorhynchus nerka). Amer. Zool. 11:99-113.

Cairns, J., Jr. and J. R. Pratt. 1993. A history of biological monitoring using benthic macroinvertebrates, pp. 10-27. Un D.M. Rosenberg and V.H. Resh (eds.) Freshwater biomonitoring and benthic macroinvertebrates. Chapman and hall, NY. 488 pp.

Calhoun, A. (Ed.). 1966. Inland fisheries management. Calif. Dept. Fish and Game, Sacramento. 546 p.

Cederholm, C. J., L. M. Reid and E. O. Salo. 1980. Cumulative Effects of Logging Road Sediment on Salmonid Populations in the Clearwater River, Jefferson County, Washington. Pages 38-74 in WWRC (1981).

Clemmons, M.M. 2000. Biological Benefits of Stream Restoration. Opening address presented at the 2000 NC Stream Restoration Institute Conference. Boone, NC.

Coble, D. W. 1961. Influence of water exchange and dissolved oxygen in redds on survival of steelhead trout embryos. Transactions of the American Fisheries Society 90:469-474.

Copeland, R.R, D.N. McComas, C.R. Thorne, P.J. Soar, M.M. Jones, and J.B. Fripp. 2001. United States Army Corps of Engineers (USACOE). Hydraulic Design of Stream Restoration Projects. Washington, DC.

Corn, P. S., and R. B. Bury. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management 29:39-57.

Cowan, W.L. 1956. "Estimating Hydraulic Roughness Coefficients." Agricultural Engineering, Vol. 37, No. 7, pp. 473-475

Fausch, K. D., C. L. Hawkes, and M. G. Parsons. 1988. Models that predict the standing crop of stream fish from habitat variables: 1950–85. General Technical Report PNW

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream corridor restoration: Principles, processes and practices. National Technical Information Service. Springfield, VA.

Fischenich, C. and R. Seal. 1999. Boulder Clusters. EMRRP Technical Notes Collection (TNEMRRP-SR-11) U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp

Fischer, R. A. and J. C. Fischenich. 2000. Design Recommendations for Riparian Corridors and Vegetated Buffer Strips. U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp

Fisher, S. G. and G. E. Likens. 1973. Energy flow in Bear Brook, New Hampshire: an integrative approach to stream ecosystem metabolism. Ecological Monographs 43:421-439.

Flebbe, P. A. and C. A. Dolloff. 1995. Trout use of Woody Debris and Habitat in Appalachian Wilderness Streams in North Carolina. North American Journal of Fisheries Management 15:579-590.

Flebbe, P. A., L. D. Roghair, and J. L. Bruggink. 2006. Spatial Modeling to Project Southern Appalachian Trout Distribution in a Warmer Climate. Transactions of the American Fisheries Society. 135:1371-1382.

Friel, E.A., T.A. Ehlke, W.A. Hobba, Jr., S.M. Ward, and R.A. Shultz. 1984. Hydrology of area 8, eastern coal province, West Virginia and Ohio. United States Geological Survey Open File Report 84-463.

Gentry, A.; D. Word, M. Carreira, J. Jack. 2005. Leaf litter decomposition as a functional assessment of a natural stream channel design project. Eos. Trans. AGU, 85(18) Jt. Assem. Supplement, Abstract NB33E-10.

Gerritsen, J., J. Burton, and M. T. Barbour. 2000. A Stream Condition Index for West Virginia Wadeable Streams. Tetra Tech, Incorporated; Owings Mills, Maryland for U. S. Environmental Protection Agency, Region 3 Environmental Services Division and Office of Science and Technology, Office of Water, Washington, D. C.

Gorman, O.T. and J.R. Karr. 1978. Habitat Structure and Stream Fish Communities. Ecology. 59:507-515.

Gray, D. H. and A. T. Leiser 1982. Biotechnical slope protection and erosion control. Van Nostrand Reinhold, New York, 271 pp.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An Ecosystem Perspective of Riparian Zones. BioScience 41(8):540-551.

Hallock, R.J., R. F. Elwell, and E. H. Fry, Jr. 1970. Migrations of adult king salmon Oncorhynchus tshawytscha in the San Joaquin Delta as demonstrated by the use of sonic tags. California Department of Fish and Game, Fish bulletin 151.

Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.O. Slate, A.G. Jessup, J.R. Everhart, and R.E. Smith. 1999. Bankfull hydraulic geometry relationships for North Carolina streams. *Wildland Hydrology.* AWRA Symposium Proceedings. D.S. Olsen and J.P. Potyondy, eds. American Water Resources Association. June 30-July 2, 1999. Bozeman, MT.

Inglis, C.C. 1947. Meanders and their bearing on river training. Institution of Civil Engineers. Maritime and Waterways Engineering Division. Paper No. 7: 54 pp.

Jarrett, Robert D. 1984. “Hydraulics of High-Gradient Streams.” Journal of Hydraulic Engineering, ASCE, Vol. 110, No. 11, pp. 1519-1539.

Knighton, D. 1998. Fluvial Forms and Processes – A New Perspective. London: Arnold Publishers.

Krebs, C. 1998. Ecological Methodology for Windows: Krebs/WIN. Version 3.1:.Volume 9.0. University of California, Berkley, Calif.

Kuehne, R.A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecology 43:608-614.

Lane, E. W. 1955. Design of stable channels. Transactions of the American Society of Civil Engineers. Paper No. 2776: 1234-1279.

Lemly, D. A. 1982. Modification of benthic insect communities in polluted streams: combined effects of sedimentation and nutrient enrichment. Hydrobiologia 87(3):229-245.

Lenat, D. R. and J. K. Crawford. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. Hydrobiologia 294(3):185-199.

Leopold, L.B., 1994. A View of the River. Cambridge: Harvard University Press.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial Processes in Geomorphology. San Francisco: W. H. Freeman and Company.

Lepori, F., D. Palm and B. Malmqvist. 2005. Effects of stream restoration on ecosystem functioning: detritus retentiveness and decomposition. Journal of Applied Ecology. 42(2):228-238.

Limerinos, J.T. 1970. "Determination of the Manning Coefficient from Measured Bed Roughness in Natural Channels." Water Supply Paper 1898-B, USGS.

Lowrance, R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, L Asmussen. 1984. Riparian Forests as Nutrient Filters in Agricultural Watersheds. BioScience 34(6):374-377.

Lyons, J. 1991. Predicting smallmouth bass presence/absence and abundance in Wisconsin streams using physical habitat characteristics. Pages 91-103 in D.C. Jackson, editor. The First International Smallmouth Bass Symposium. American Fisheries Society. 177 pages.

Magnuson, J. J., L. B. Crowder, and P. A. Medvick. 1979. Temperature as an ecological resource. American Zoologist. 19:331-343.

McCafferty, WP. 1981. Aquatic Entomology: the fisherman's and ecologists' illustrated guide to insects and their relatives; with illustrations by Arwin V. Provonsha. Boston, Mass.: Science Books International.

McCandless, T. L. 2003. Maryland stream survey: Bankfull discharge and channel characteristics of streams in the Allegheny Plateau and the valley and ridge hydrologic regions. U.S. Fish and Wildlife Service. Annapolis, MD.

Merritt, R. W. and K. W. Cummins, eds. 1996. An Introduction to the Aquatic Insects of North America, Third Edition. Kendall/Hunt Publishing Company, Dubuque, Iowa.

Mesick, C. F. 1995. Response of brown trout to streamflow, temperature, and habitat restoration in a degraded stream. Rivers. 5(2):75-95.

Minshall, G. W. 1984. Aquatic insect-substratum relationships. Pages 358-400 in The Ecology of Aquatic Insects. Reiser, D. W. and D. M. Rosenberg editors. Praeger Publishers, New York.

Monan, G. E., J. H. Johnson, and G. F. Esterberg. Electronic tags and related tracking techniques aid in study of migrating salmon and steelhead trout in the Columbia River basin. Marine Fisheries Review 37(2):9-15.

Moss D. D., Scott D. C. 1961. Dissolved-Oxygen Requirements of Three Species of Fish. Transactions of the American Fisheries Society: Vol. 90, No. 4 pp. 377–393.

Moyle P. B. and J. J. Cech, Jr. 1982. Fishes: An introduction to Ichthyology. Prentice-Hall, New Jersey.

Muotka, T. and P. Laasonen. 2002. Ecosystem recovery in restored headwater streams: the role of enhanced leaf retention. Journal of Applied Ecology 39(1):145–156.

Murphy, M. L. and W. R. Meehan. 1991. Stream Ecosystems. American Fisheries Society Special Publication. 19:83-138.

Nebeker, A. V. 1972. Effect of Low Oxygen Concentration on Survival and Emergence of Aquatic Insects. Transactions of the American Fisheries Society: Vol. 101, No. 4 pp. 675–679.

Opperman, J. J. and A. M. Merenlender. 2004. The Effectiveness of Riparian Restoration for Improving Instream Fish Habitat in Four Hardwood-Dominated California Streams. North American Journal of Fisheries Management 24:822-834.

Papanicolaou, A.N., A. Bdour, and E. Wicklein. 2004. One-dimensional hydrodynamic sediment transport model applicable to steep mountain streams. Journal of Hydraulic Research, Vol. 00. No. 0, pp 1-19, International Association of Hydraulic Engineering and Research.

Pennak, R. W. 1989. Freshwater Invertebrates of the United States: Protozoa to Mollusca, Third Edition. John Wiley and Sons, Inc., New York, New York.

Peterjohn, W. T. and D. L. Carrell. 1984. Nutrient dynamics in an agricultural watershed: observation of a riparian forest. Ecology 65:1466-1475.

Reiser, D. W. and R. G. White. 1981. Incubation of steelhead trout and spring chinook salmon eggs in a moist environment. Progressive Fish-Culturist 43:131-134.

Richards, C., G. E. Host, and J. W. Arthur. 1993. Identification of predominant environmental factors structuring stream macroinvertebrate communities within a large agricultural catchment. Freshwater Biology 29(2):285-294.

Roni, P. and T. P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences. 58(2):282-292.

Rosgen, D. L. 2001b. A Stream Channel Stability Assessment Methodology. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp. II – 18-26, March 25-29, 2001, Reno, NV.

Rosgen, D.L. 1994. A classification of natural rivers. *Catena* 22:169-199.

Rosgen, D.L. 1996. Applied River Morphology. Pagosa Springs, CO: Wildland Hydrology Books.

Rosgen, D.L. 1997. A geomorphological approach to restoration of incised rivers. Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision. Wang, S.S.Y, E.J. Langendoen, and F.D. Shields, Jr., eds. 12-22.

Rosgen, D.L. 1998. Field Guide for Stream Classification. Wildland Hydrology, Pagosa Springs, CO.: 193 pp.

Rosgen, D.L. and Silvey, H.L., 2005. The Reference Reach Field Book. Wildland Hydrology Books, Fort Collins, CO, 256 pp.

Rosgen, D.L. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology.

Schlosser, I. J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecological Monographs. Vol. 52, no. 4, pp. 395-414. 1982

Schumm, S.A. 1960. The shape of alluvial channels in relation to sediment type. US Geological Survey. Professional Paper 352-B. Washington, DC.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. Illinois Press, Urbana, Ill.

Shields, F. D., Jr. and S. Knight. 2003. Ten Years After: Stream Habitat Restoration Project in Retrospect. from Proceedings, World Water & Environmental Resources Congress. Philadelphia, P.A. June 23-26, 2003.

Simon, A. 1989. A model of channel response in disturbed alluvial channels. *Earth Surface Processes and Landforms* 14(1):11-26.

Soar and Thorne. 2001. Channel Restoration Design for Meandering Rivers. US Army Corps of Engineers. Engineering Research and Development Center. Coastal and Hydraulics Laboratory. ERDC\CHL CR-01-1. September, 2001.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/ accessed [06/27/2007].

Southerland, M.T. and Stribling J.B. 1995. Status of Biological Criteria Development and Implementation. Pages 81-96 in W.S. Davis and T.P. Simon (editors). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, Florida.

Sparks, E.J., Townsend, J. M., Hagman, T., and D. Messer. Spring 2003b. Stream assessment protocol for headwater streams in the Eastern Kentucky Coalfield region. Aquatic Resources News. Vol. 2, Issue 1.

Strausbaugh, P.D.; Core, E.L. 1978. Flora of West Virginia. Grantsville, West Virginia: Seneca Books, Incorporated. 1079p.

Sylte, T. and C. Fischenich. 2000. Rootwad Composites for Streambank Erosion Control and Fish Habitat Enhancement. EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-21), U. S. Army Engineer Research and Development Center, Vicksburg, MS. http://www.wes.army.mil/el/emrrp

Thorne, C. R., and L. W. Zevenbergen. 1985. Estimating mean velocity in mountain rivers. Journal of the Hydraulics Division, ASCE, Vol. III, No. 4, pp. 612-624.

U.S. Army Corps of Engineers (USACE). 2008. Regulatory Guidance Letter 02-2, Guidance on Compensatory Mitigation Projects for Aquatic Resources Final Rule. March 31, 2008.

U.S. Army Corps of Engineers (USACE). 2008. Regulatory Guidance Letter 08-2, Guidance on Jurisdictional Determinations. June 26, 2008.

U.S. Army Corps of Engineers (USACE). 2002. Agreement Concerning In Lieu Mitigation Fees Between Kentucky Department of Fish and Wildlife Resources and U.S. Army Corps of Engineers. October 18, 2008.

United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), Web Soil Survey 1.1. Current (June 2007). Soil Survey of Boone and Lincoln Counties, West Virginia; info not available in print.

USDA, NRCS. 2007. The PLANTS Database (http://plants.usda.gov, 27 June 2007). National Plant Data Center, Baton Rouge, LA 70874

USDA, NRCS. In Press. Chapter 11: Rosgen Geomorphic Channel Design in Part 654 Stream Restoration Design National Engineering Hanbook.

USEPA. 2000. "Interim Chemical/Biological Monitoring Protocol for Coal Mining Permit Applications." Region 3.

USEPA. 2005. Watershed Assessment of River Stability and Sediment Supply. Available online at http://www.epa.gov/warsss/. Accessed July 12, 2007.

Vannote, R.L., G.W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences. 37:130-137.

Wallace, J. B., J. R. Webster, and J. L. Meyer. 1995. Influence of log additions on physical and biotic characteristics of a mountain stream. Canadian Journal of Fisheries and Aquatic Sciences. 52(10):2120-2137.

Wang, L., J. Lyons, and P. Kanehl. 2002. Effects of Watershed Best Management Practices on Habitat and Fish in Wisconsin Streams. Journal of the American Water Resources Association 38(3):663-680.

Warren, C.E. 1971. Biology and water pollution control. W.B. Saunders, Philadelphia. 434 pp.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7.

Wetzel, R. G. 1983. Limnology. 2nd ed. Saunders College Publishing, Philadelphia.

Wilhm, J.L. and T. C. Dorris. 1968. Biological parameters of water quality. Bioscience 18:447-481.

Wohl, E.E. 2000. Mountain Rivers. Am. Geophys. Union Press. 320 pp.

Wolman, G.M. 1954. A method of sampling coarse river-bed material. Trans. Am. Geophysical Union, Vol. 35, No. 6.

Wynn, T. M. and S. Mostaghimi. 2006. Effects of riparian vegetation on stream bank subaerial processes in southwestern Virginia, USA. Earth Surf. Process. Landforms. 31:399-413.

Wynn, T. M., S. Mostaghimi, J. A. Burger, A. A. Harpold, M. B. Henderson and L.-A Henry. 2004. Variation in Root Density along Stream Banks. J. Environ. Qual. 33:2030-2039.

Figures

1.0 SECTION 1

2.0 SECTION 2

3.0 SECTION 3

4.0 SECTION 4

5.0 SECTION 5

1.0 SECTION 1

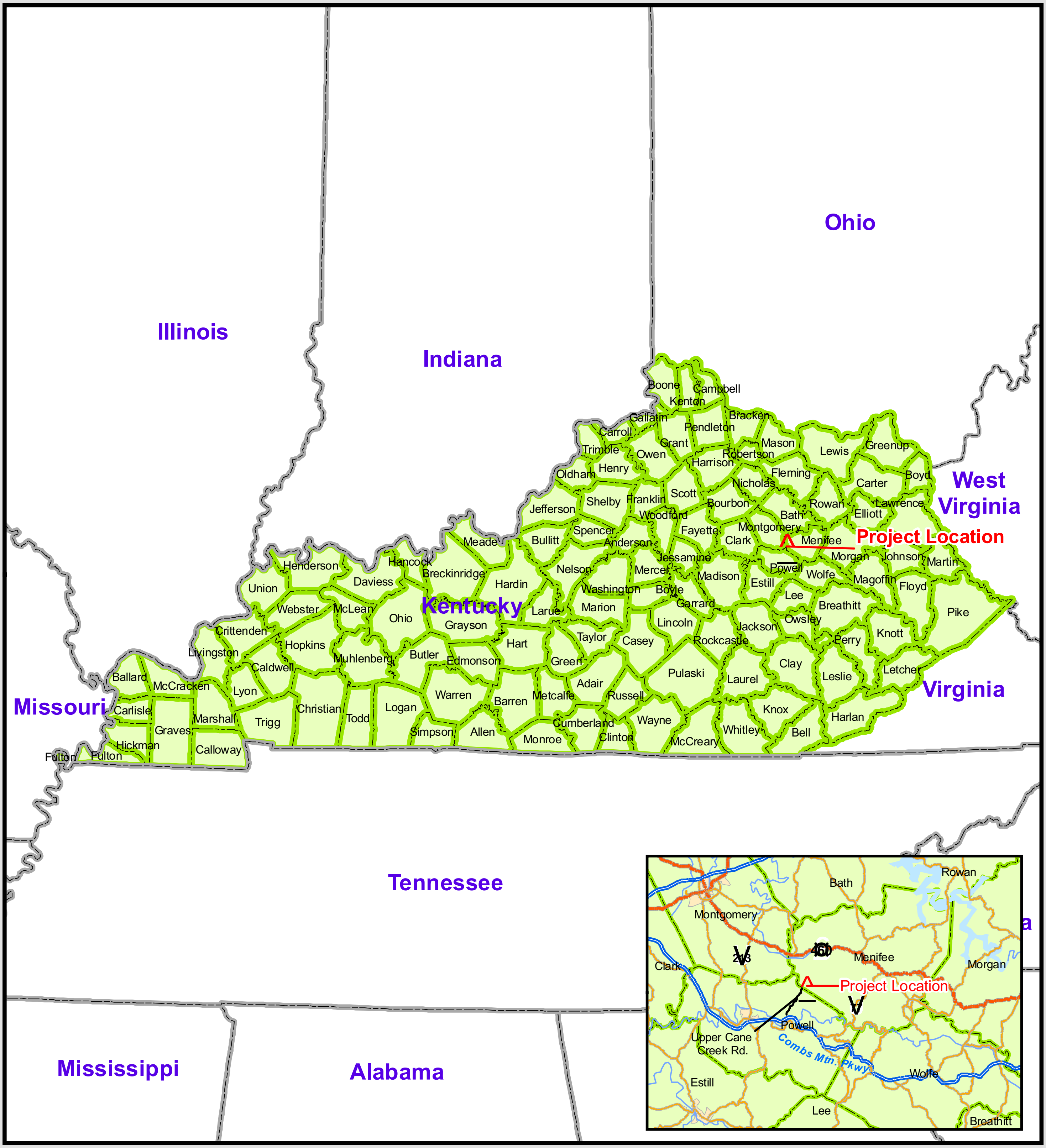


FIGURE 1.1 - PROJECT LOCATION

60 0 60 Miles

90 45 0 90 Kilometers

®

Kentucky Department of Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

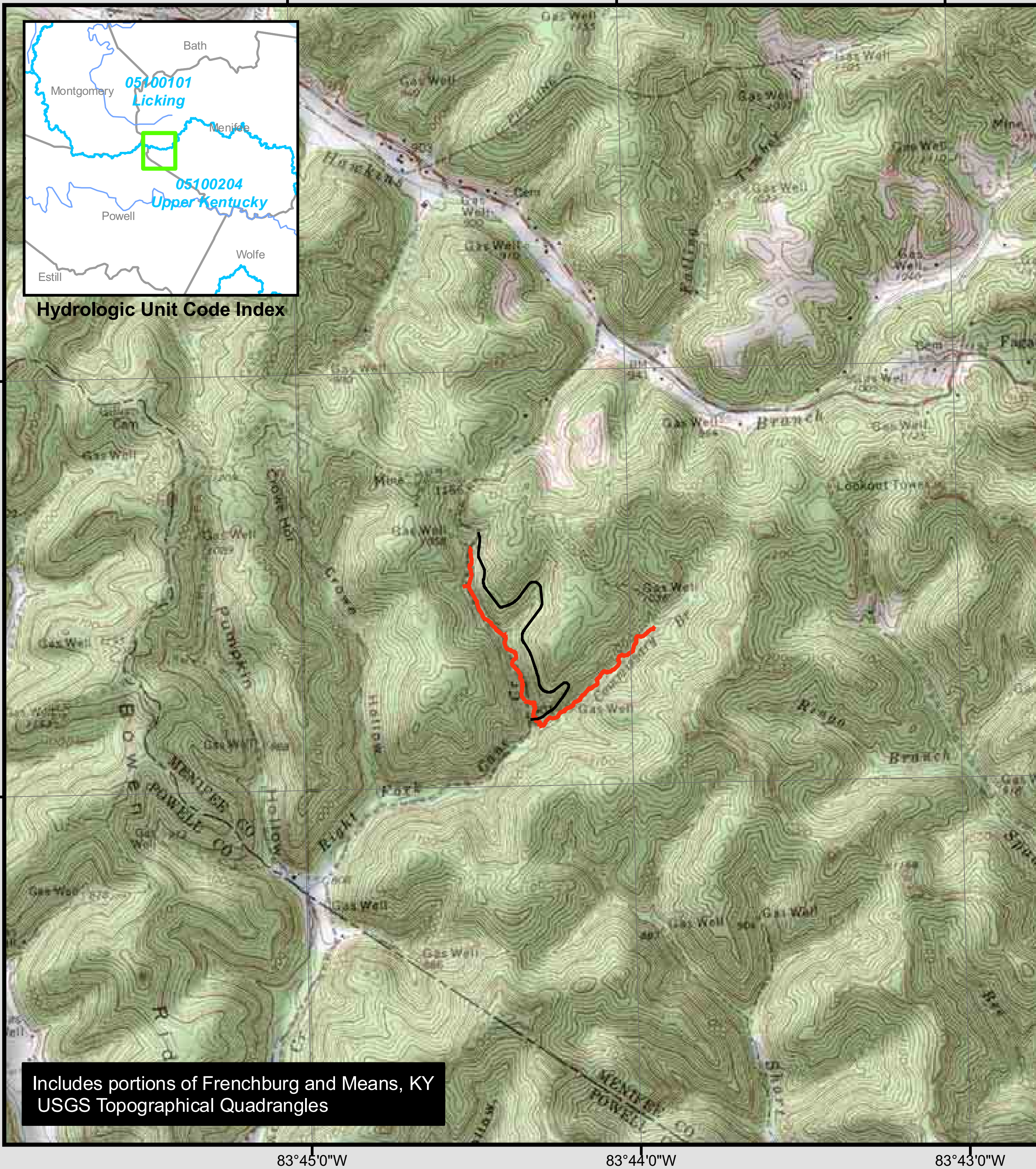


FIGURE 1.2 - TOPOGRAPHICAL MAP OF PROJECT REACHES

Mitigation Project Reach

Proposed Road Relocation

2,000 0 2,000 Feet

600 300 0 600 Meters

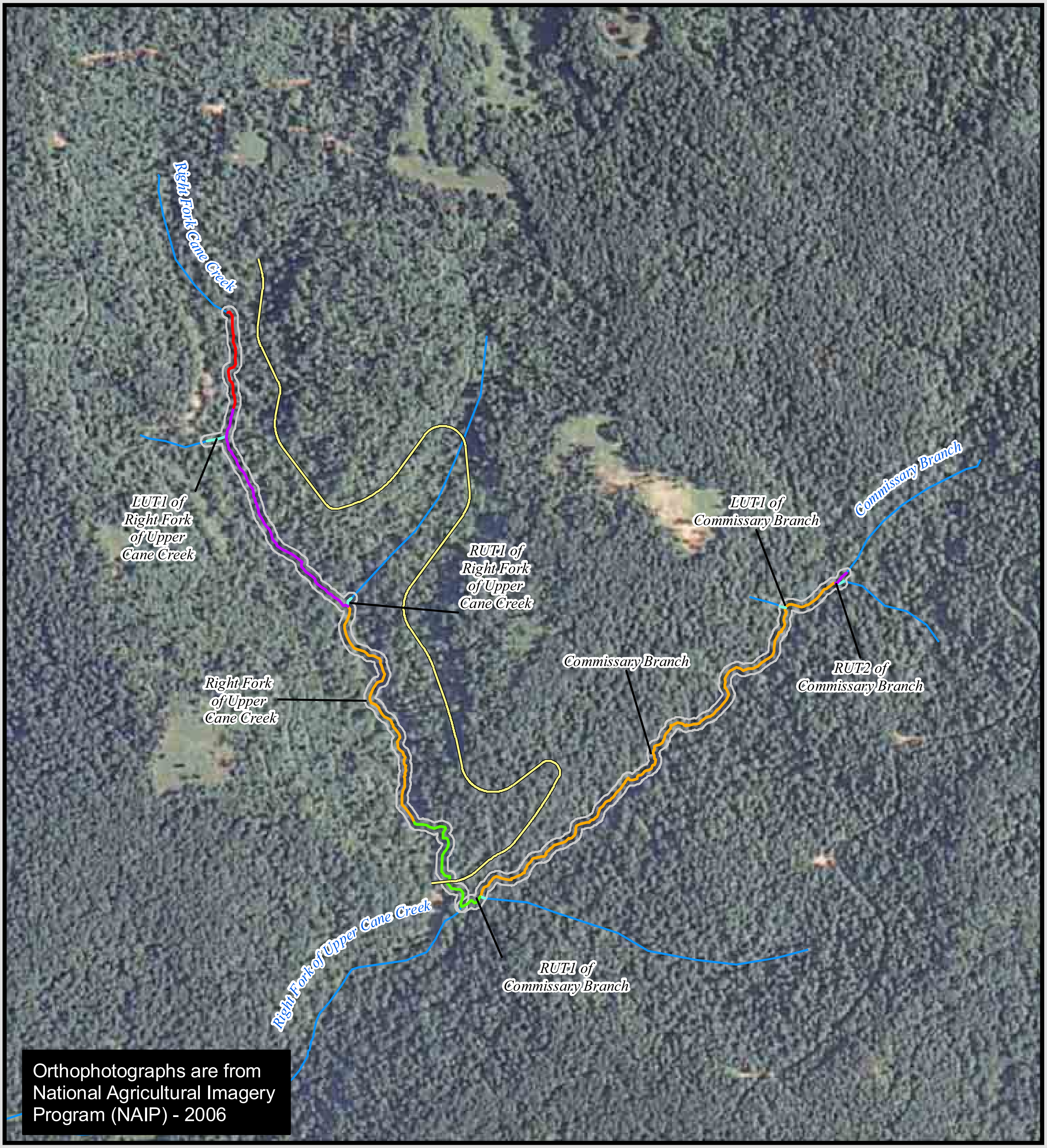


FIGURE 1.3 - AERIAL MAP OF PROJECT REACHES

Reach 1
Reach 2
Reach 3
Reach 4
Tributary
Proposed Road Relocation
Project Area*

*Includes 25ft riparian buffer

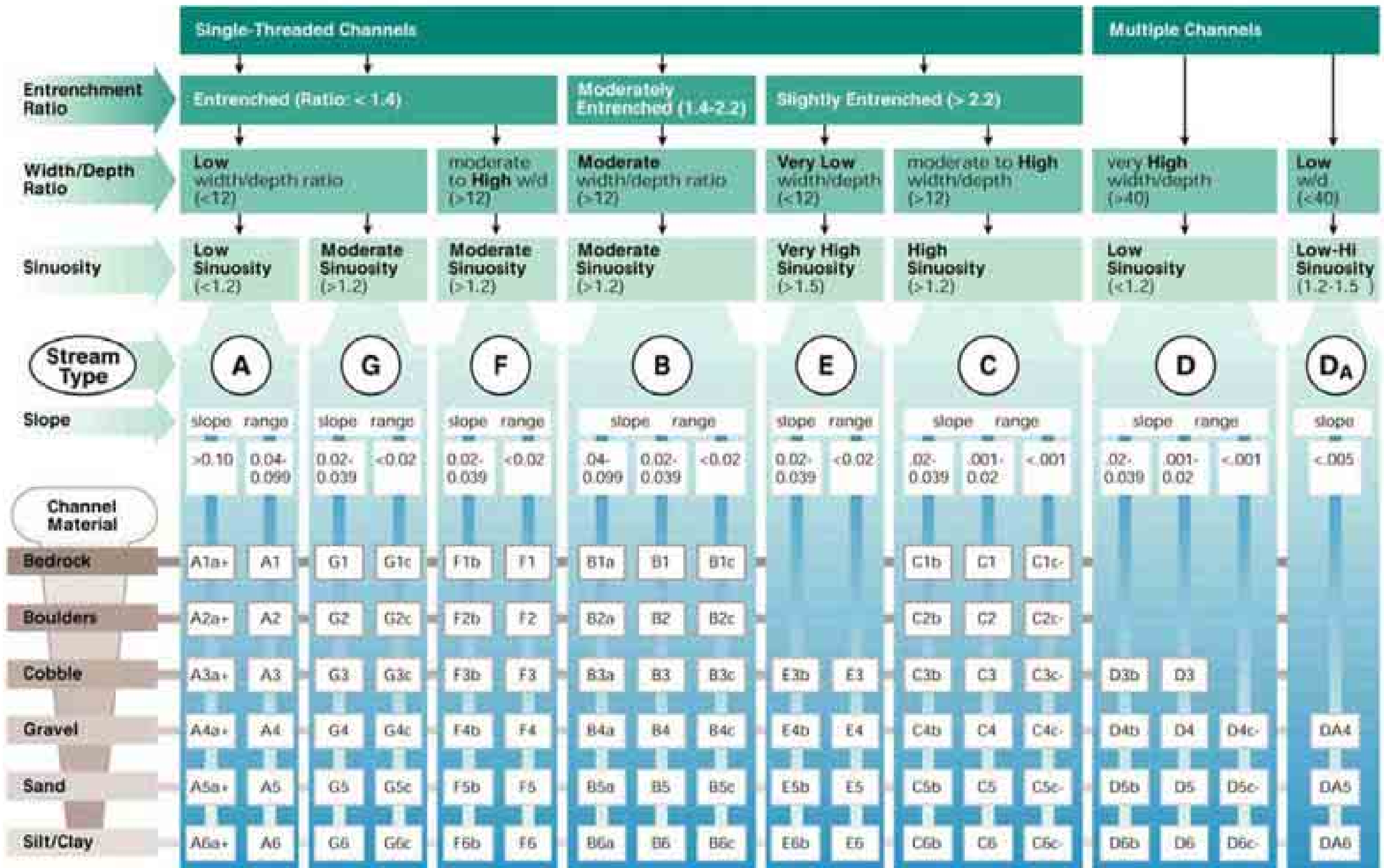
600 0 600 Feet

150 0 150 Meters

Baker

KENTUCKY DEPT. OF FISH & WILDLIFE RESOURCES

2.0 SECTION 2

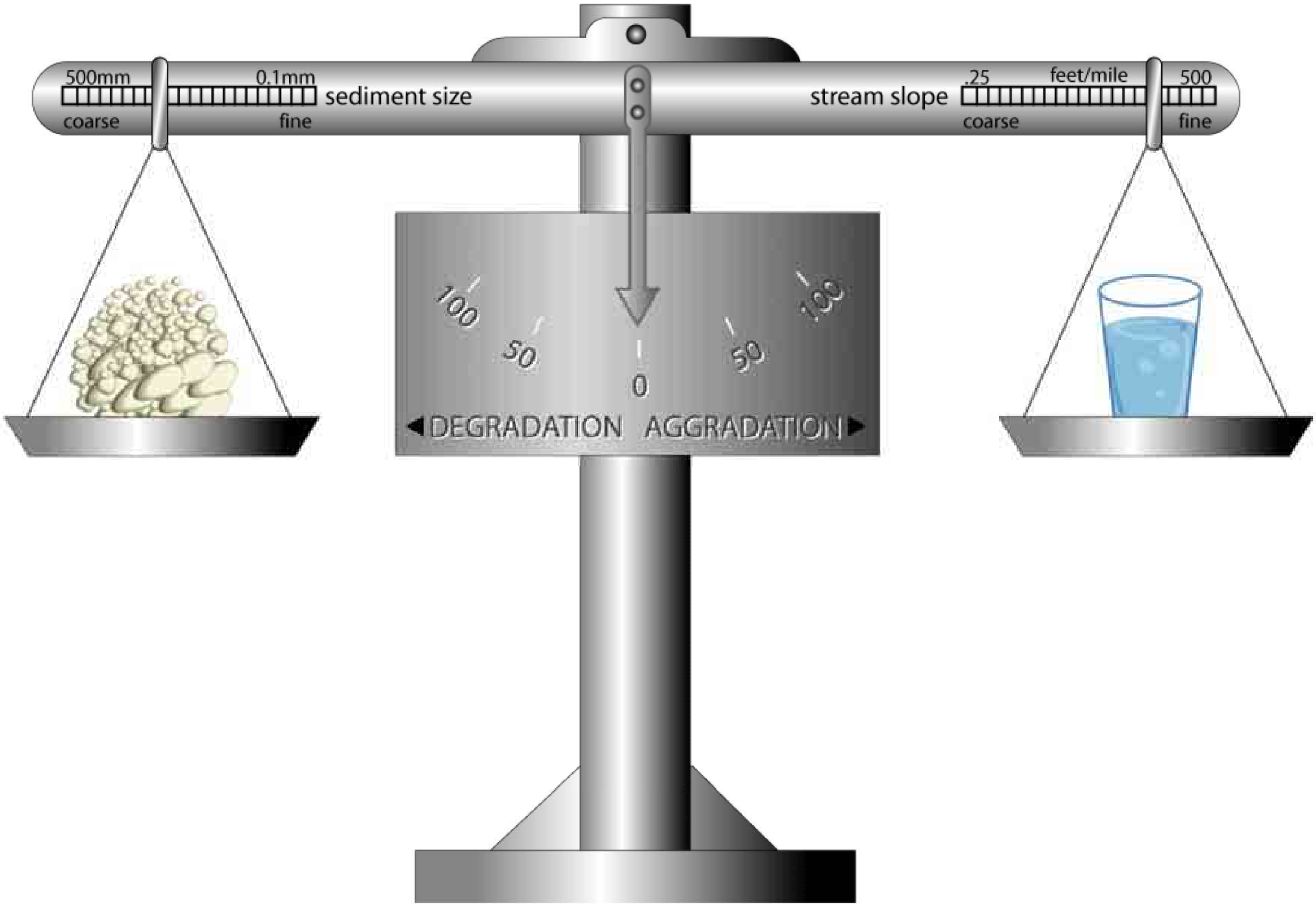


Source: Rosgen 1996. Published by permission of Wildland Hydrology.

Fig. 7.12 -- Rosgen's stream classification system (Level II).
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

Source: Rosgen, David L., Applied River Morphology, Wildland Hydrology, 1996

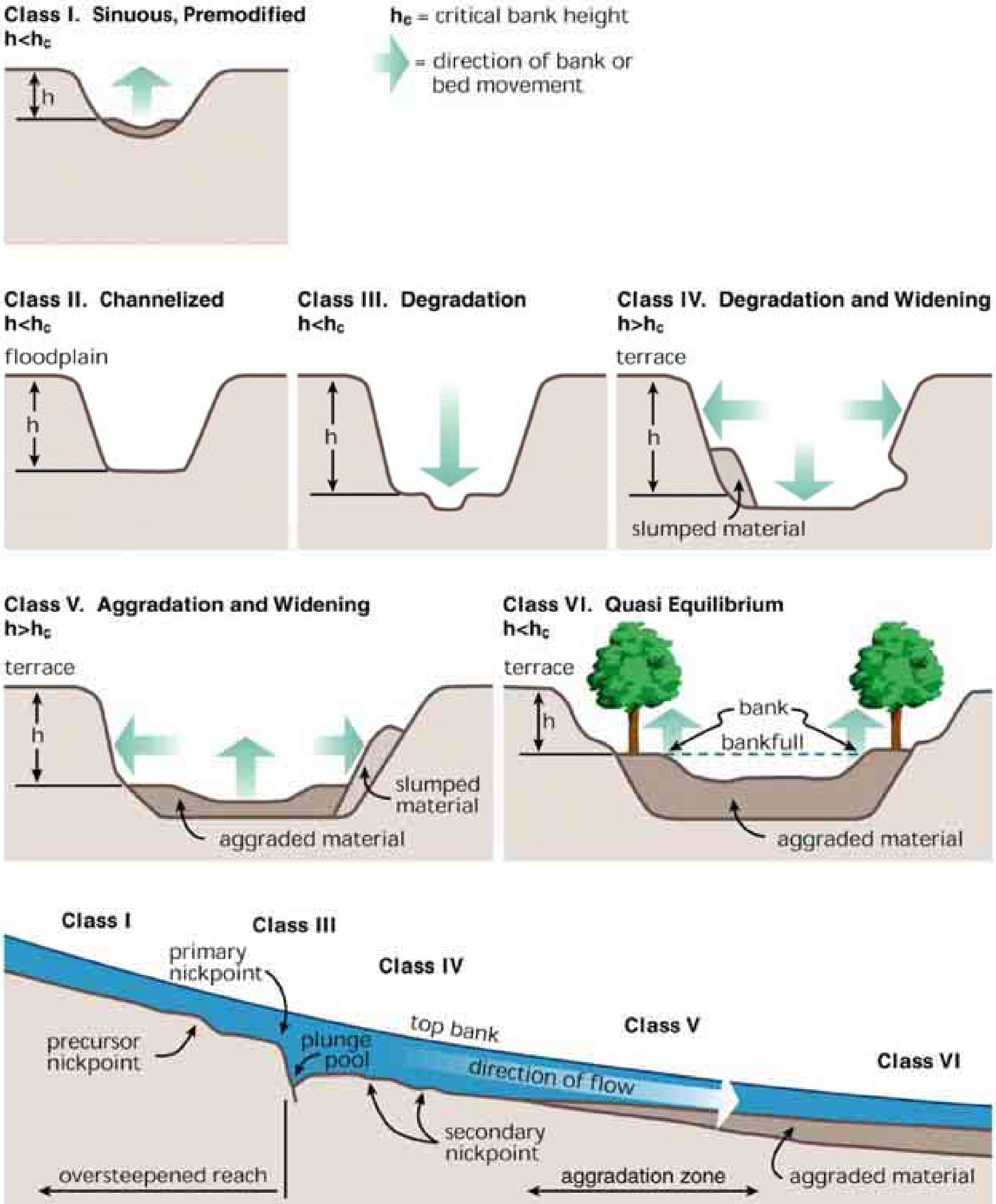
FIGURE 2.1 – ROSGEN STREAM CLASSIFICATION
Kentucky Department of Fish and Wildlife Resources 1 Sportsman's Lane Frankfort, KY 40601 800-858-1549



After: Lane, 1955

FIGURE 2.2 – FACTORS INFLUENCING STREAM STABILITY

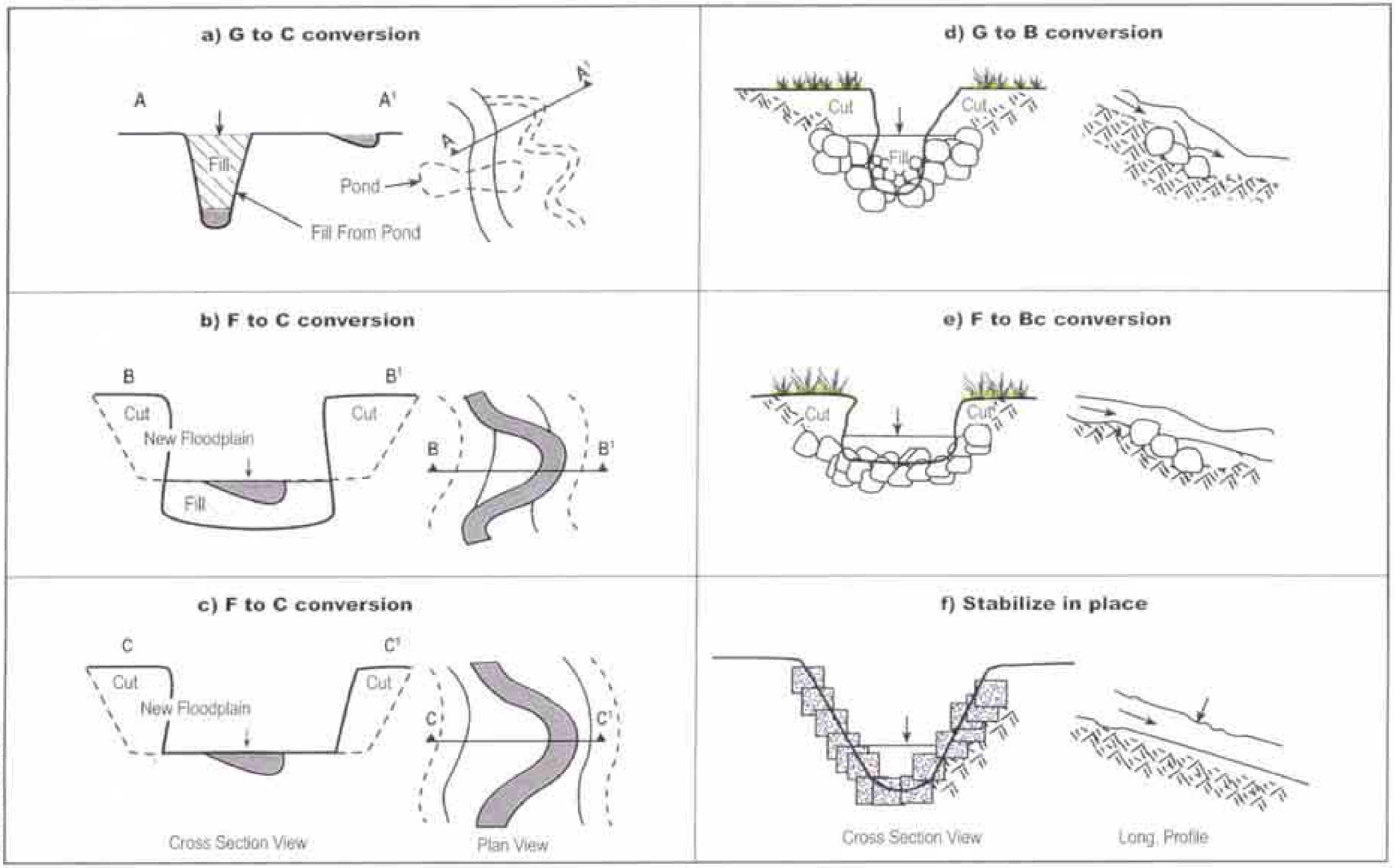
Kentucky Department of
Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549



Source: Simon, 1989; US Army Corps of Engineers, 1990.
Fig. 7.14 -- Channel evolution model..
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

FIGURE 2.3 – SIMON CHANNEL EVOLUTION MODEL

Kentucky Department of
Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

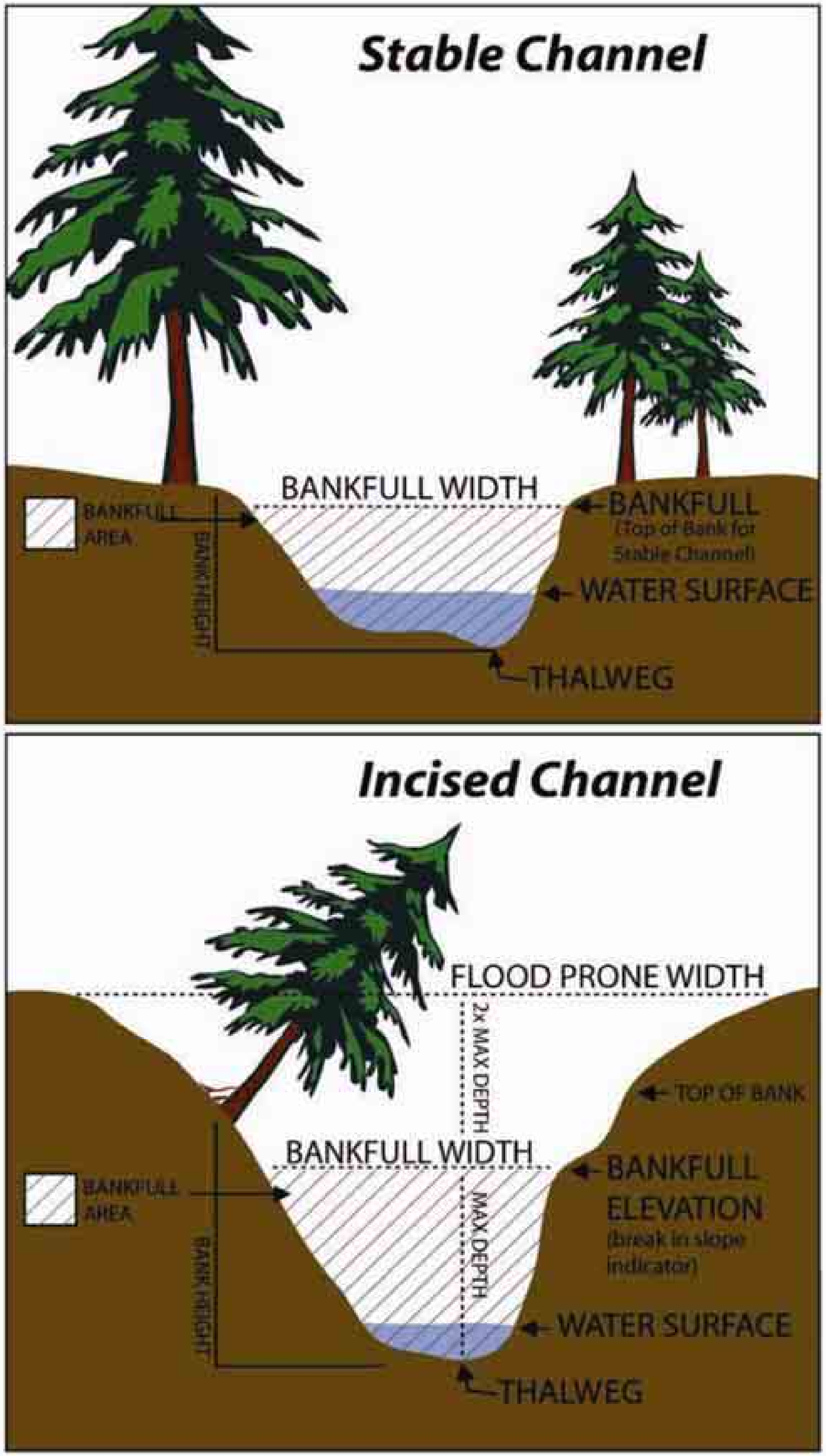


Source: Rosgen, David L., "A Geomorphological Approach to Restoration of Incised Rivers," *Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision*, 1997

FIGURE 2.4 – FACTORS INFLUENCING STREAM STABILITY

Kentucky Department of
Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

Baker



Channel Dimension Measurements

Bankfull Elevation is associated with the channel forming discharge. It is the point where channel processes and flood plain processes begin.

Bankfull width: the distance between the left bank bankfull elevation and the right bank bankfull elevation

Bankfull mean depth: the average depth from bankfull elevation to the bottom of the stream channel

Max depth (dmax): the deepest point within the cross-section measured to the bankfull elevation

Width to Depth Ratio: Bankfull width ÷ Bankfull mean depth

Bank Height Ratio: Bank height (measured from top of bank to the bottom of the stream channel) ÷ the max depth of the bankfull elevation (dmax)

Flood Prone Width: Width measured at the elevation of two times (2x) the maximum depth at bankfull (dmax)

Entrenchment Ratio: Floodprone width ÷ bankfull width

FIGURE 2.5 – CHANNEL DIMENSION MEASUREMENTS

Kentucky Department of
Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

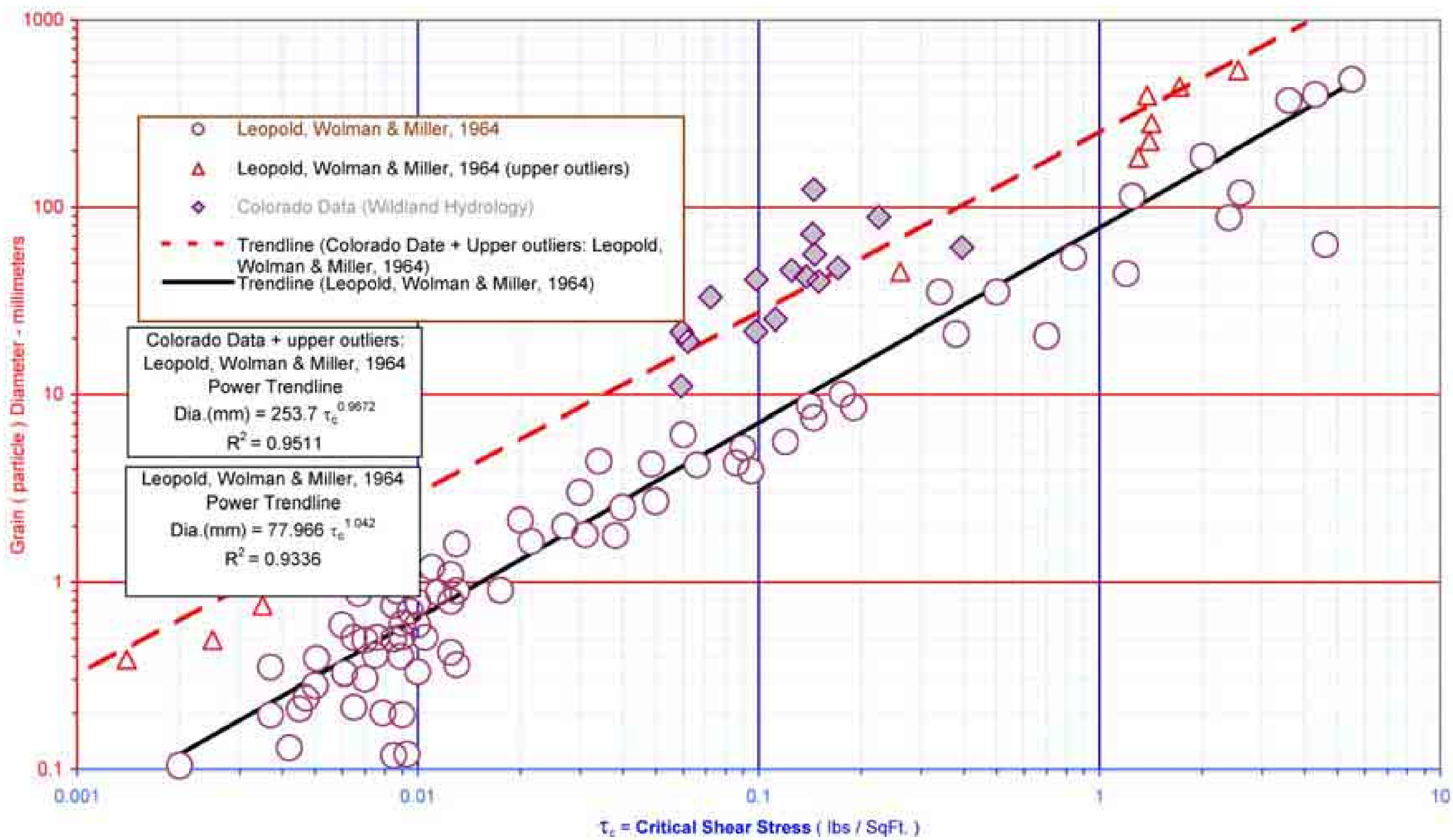


FIGURE 2.6 – CRITICAL SHEAR STRESS CURVE (FROM USEPA WATERSHED ASSESSMENT OF RIVER STABILITY & SEDIMENT SUPPLY (WARSSS) v1.0)

Kentucky Department of
Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

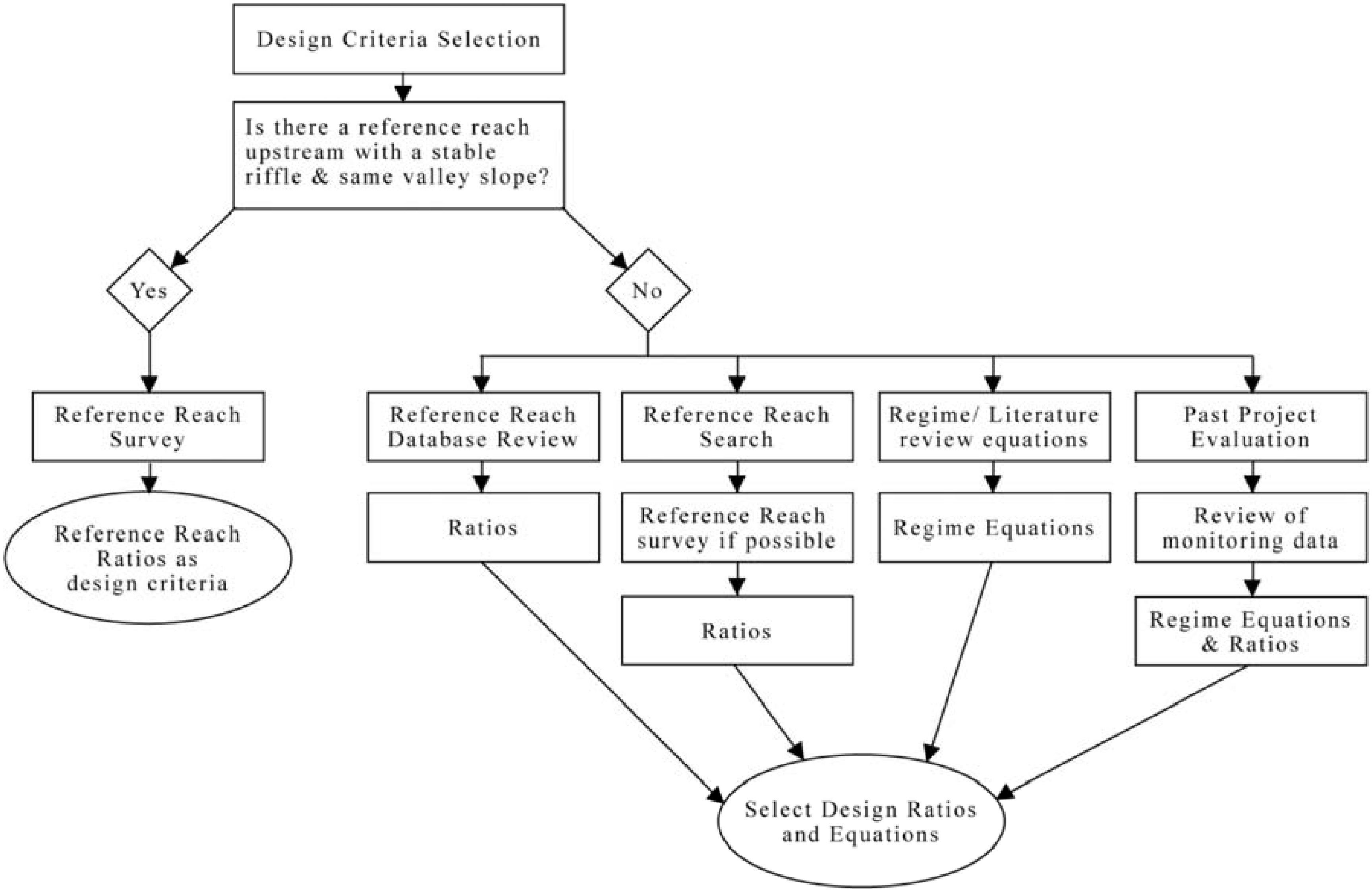


FIGURE 2.7 – DESIGN CRITERIA SELECTION

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1 Sportsman's Lane
Frankfort, KY 40601
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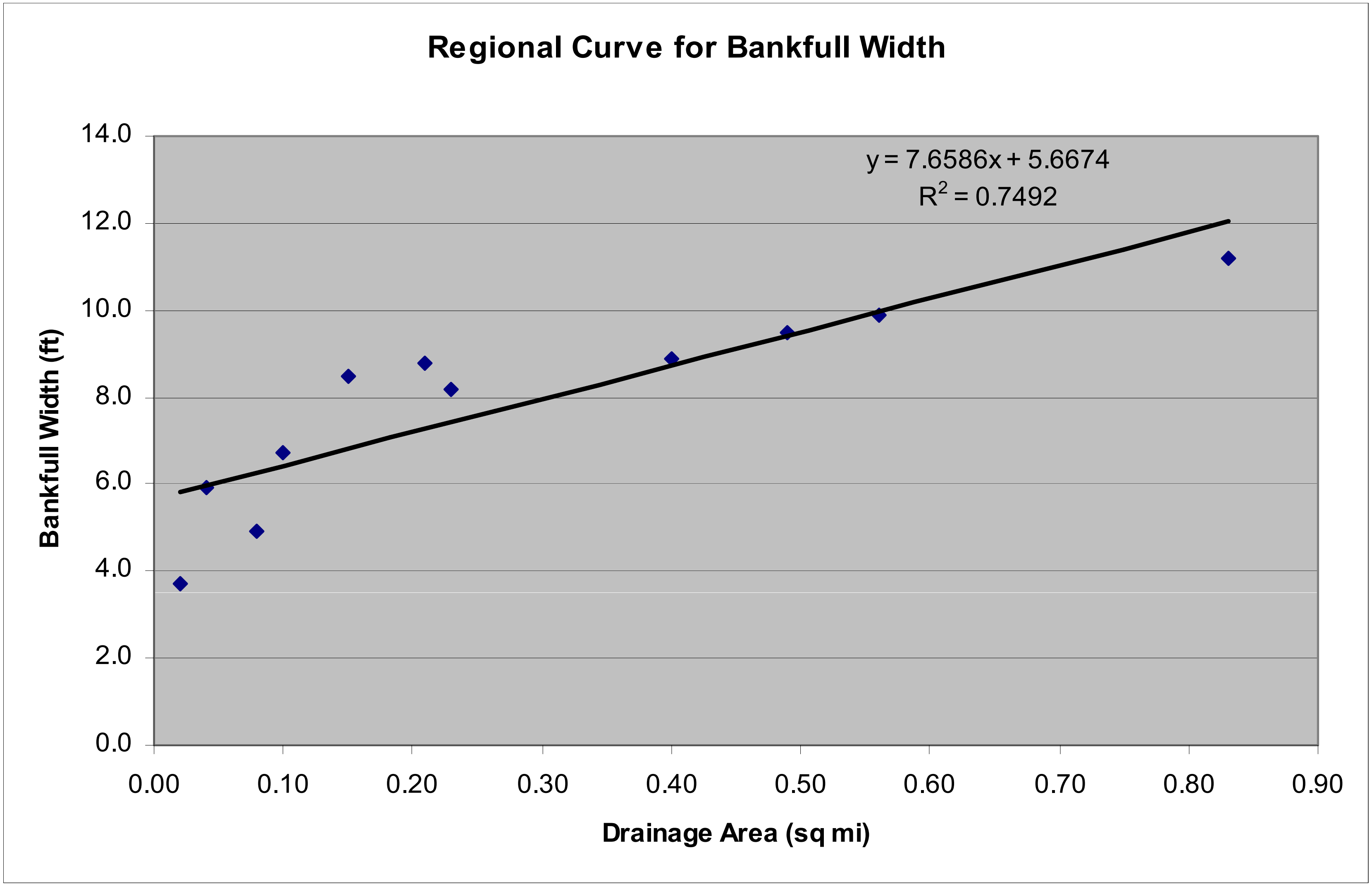

FIGURE 2.8 – BANKFULL WIDTH REGIONAL CURVE

Kentucky Department of
Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

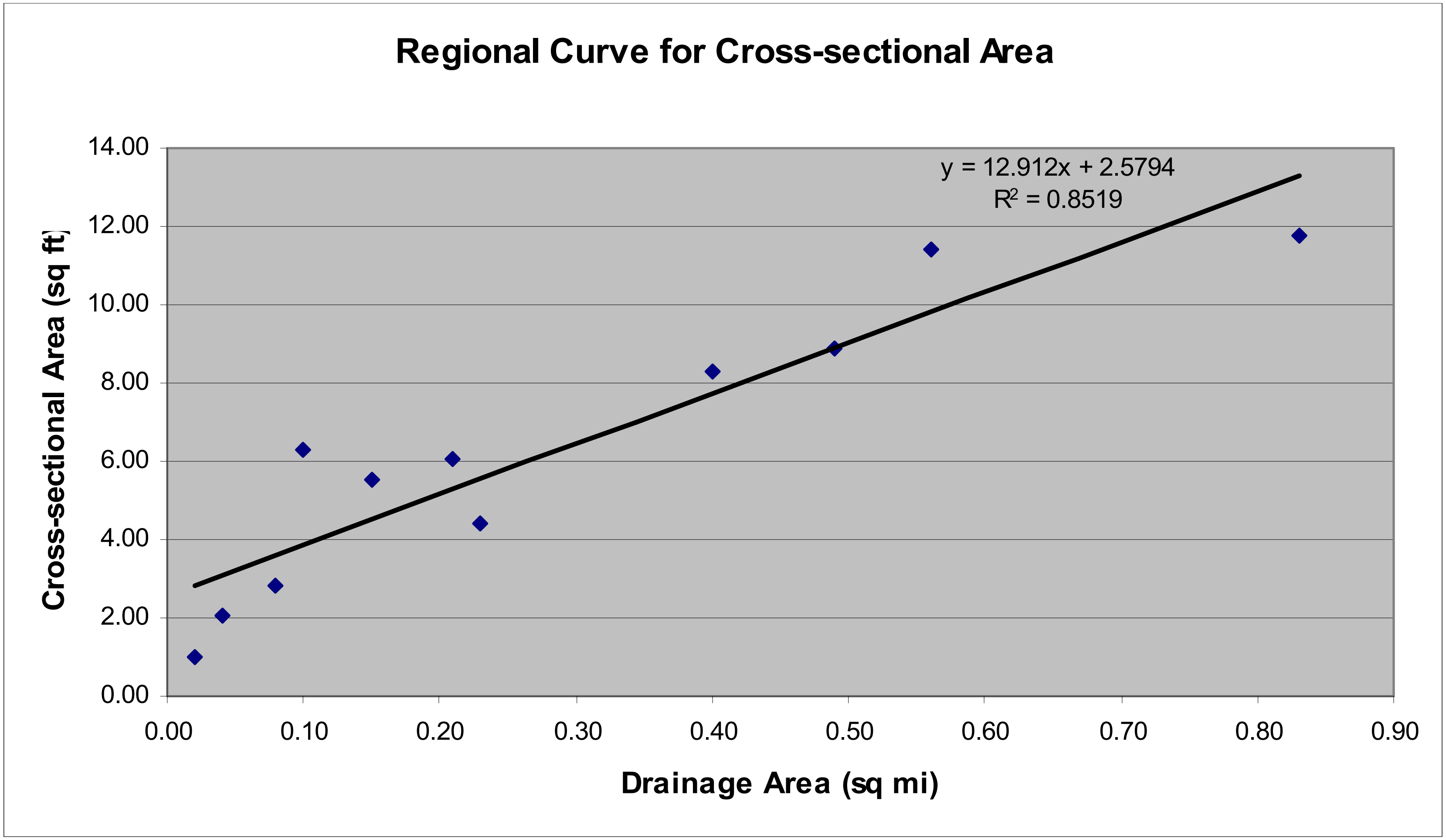

FIGURE 2.9 – CROSS-SECTIONAL AREA REGIONAL CURVE

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Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

J-Hook

Double Wing Deflector

Double Drop Rock Cross Vane

Rock Vane

FIGURE 2.10 – EXAMPLES OF IN-STREAM STRUCTURES

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Fish and Wildlife Resources
1 Sportsman's Lane
Frankfort, KY 40601
800-858-1549

Baker

3.0 SECTION 3

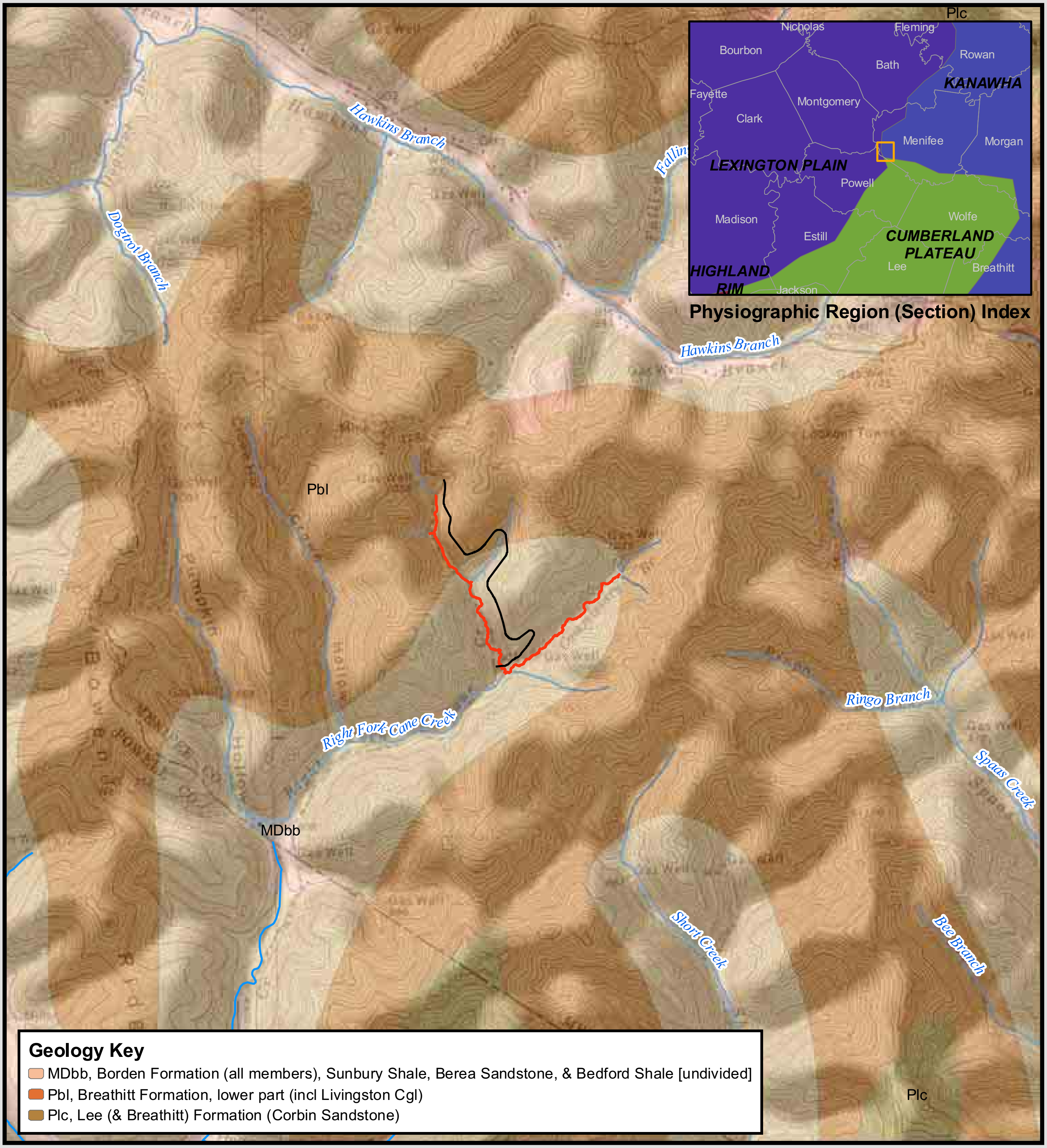

FIGURE 3.1 - AERIAL MAP OF AREA GEOLOGY

Proposed Road Relocation
Mitigation Project Reach

2,000 0 2,000 Feet

600 0 600 Meters

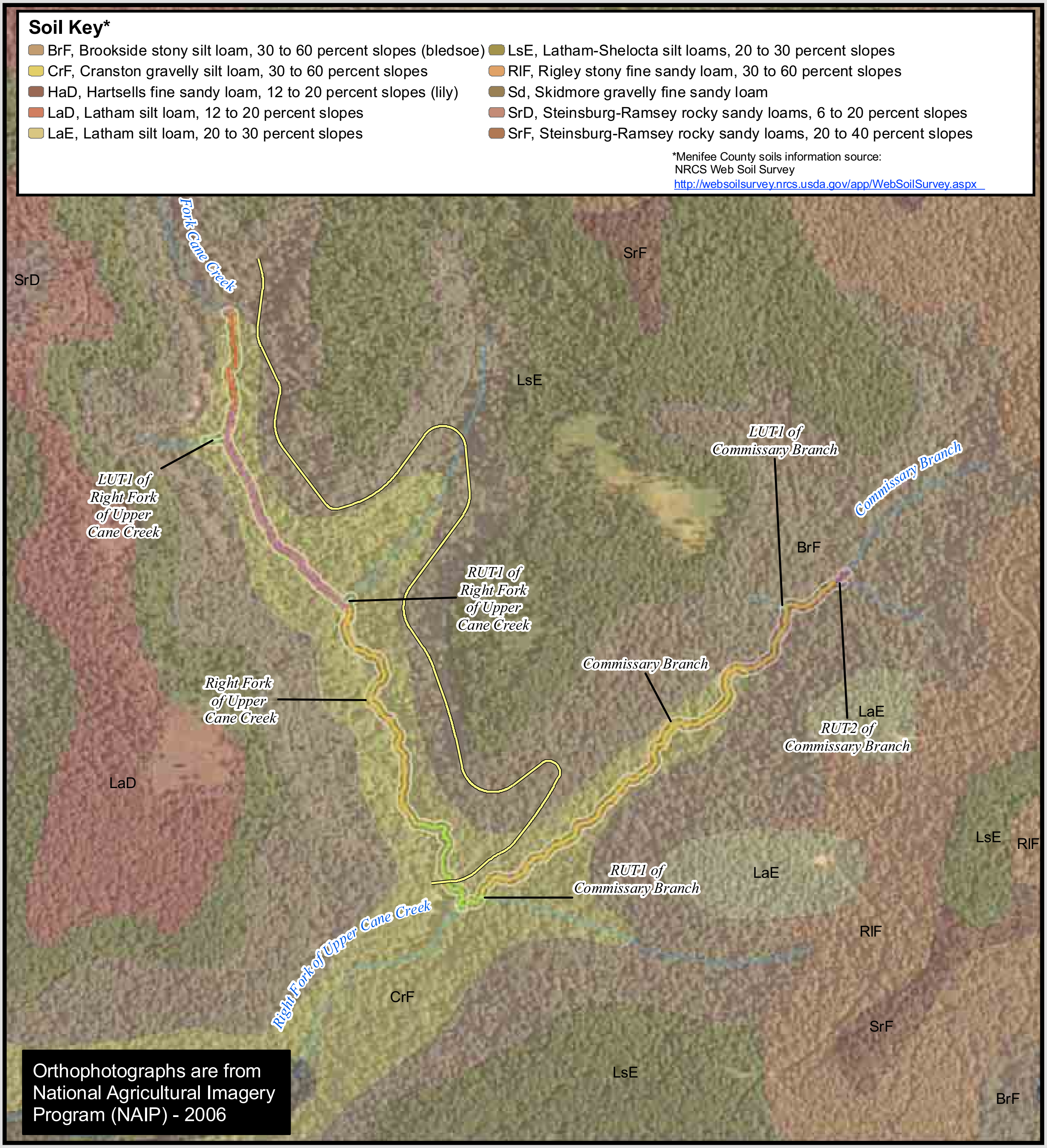

FIGURE 3.2 - AERIAL MAP OF PROJECT AREA SOILS

Reach 1
Reach 2
Reach 3
Reach 4
Tributary
Proposed Road Relocation
Project Area*

*Includes 25ft riparian buffer

600 0 600 Feet

150 0 150 Meters

4.0 SECTION 4

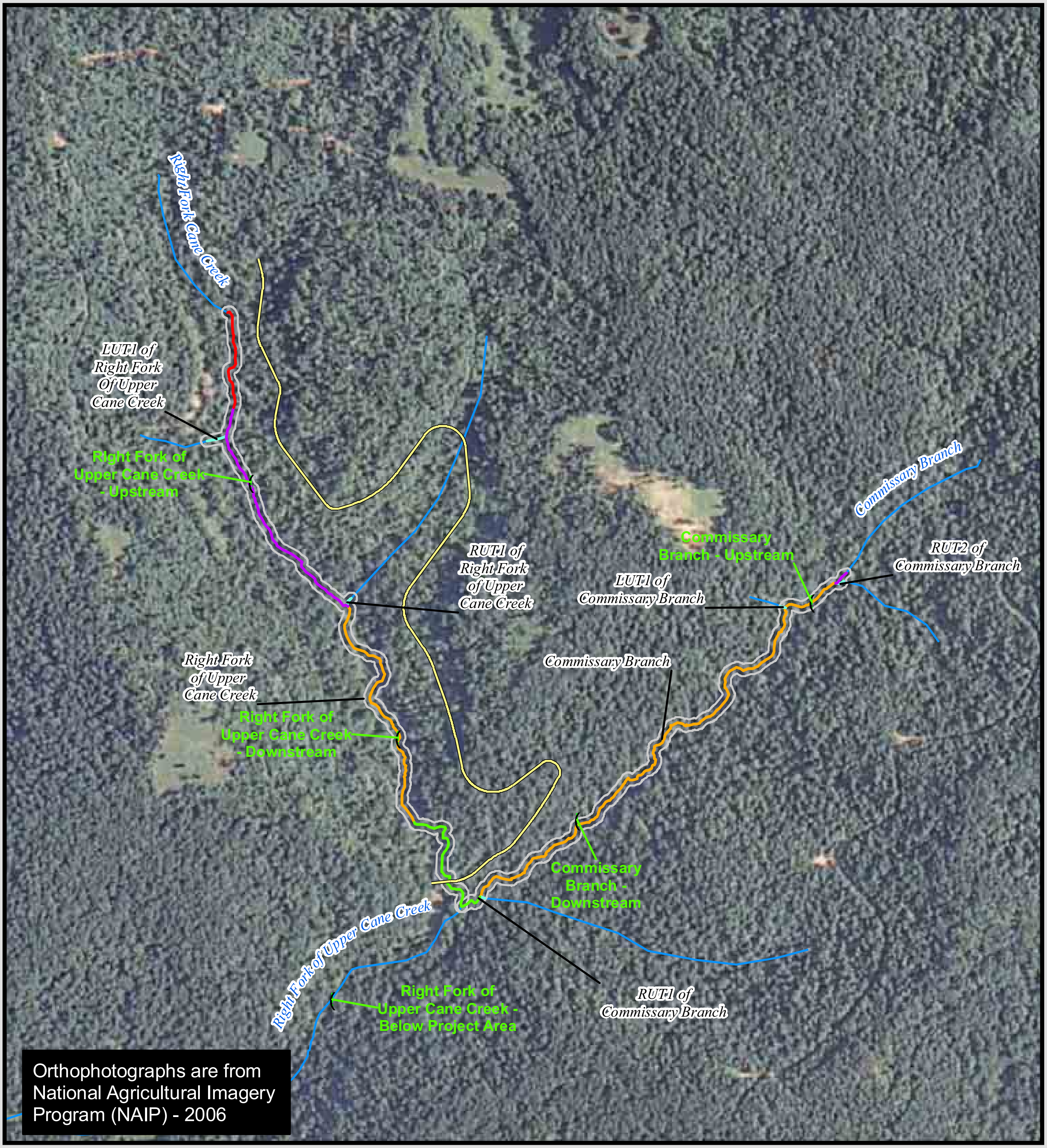

FIGURE 4.1 - AERIAL MAP OF BIOTIC SURVEYS

Reach 1
Reach 2
Reach 3
Reach 4
Tributary
Proposed Road Relocation
Project Area*
Biotic Survey Site**

*Includes 25ft riparian buffer
**Benthic Macroinvertebrate Sample, HAV, and Water Quality

600 0 600 Feet
150 0 150 Meters

Baker

5.0 SECTION 5

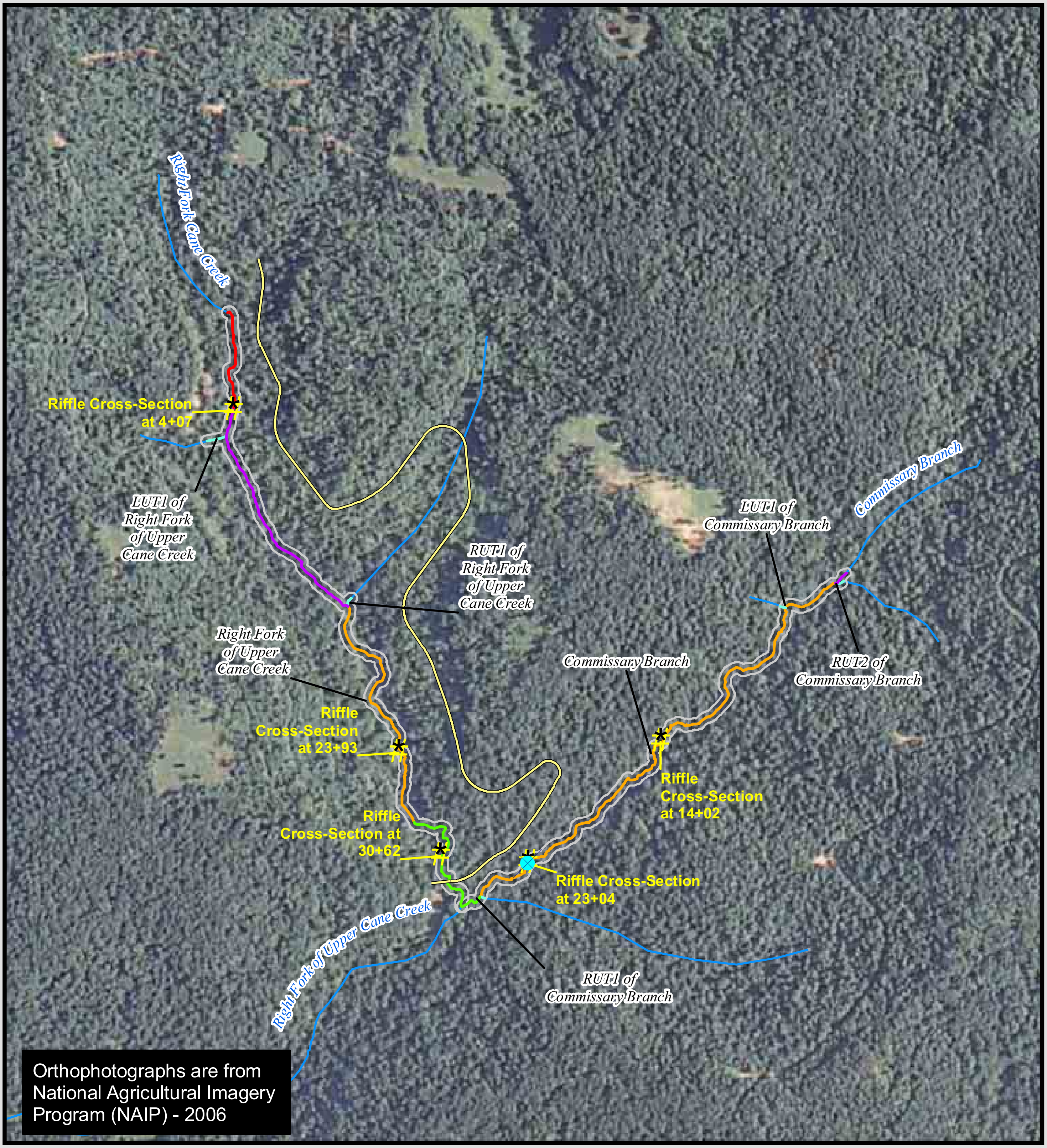

FIGURE 5.1 - AERIAL MAP OF REACH CROSS-SECTIONS

Reach 1
Reach 2
Reach 3
Reach 4
Tributary
Proposed Road Relocation
Riffle Cross-Section
Project Area*
*Includes 25ft riparian buffer

600 0 600 Feet
150 0 150 Meters

Baker

KENTUCKY DEPT. OF FISH & WILDLIFE RESOURCES

APPENDIX A

BIOLOGICAL ASSESSMENT

CONCURRENCE LETTER

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Kentucky Ecological Services Field Office
330 West Broadway, Suite 265
Frankfort, Kentucky 40601
(502) 695-0468

October 1, 2008

Mr. Mike Hardin
Kentucky Department of Fish and Wildlife Resources
#1 Sportsman's Lane
Frankfort, KY 40601

Subject: FWS #2009-B-0031, Upper Cane Creek of the Red River, Proposed Stream Restoration and Enhancement, Menifee County, Kentucky

Dear Mr. Hardin:

We received your letter dated September 12, 2008 and the enclosed Biological Assessment (BA) prepared for the proposed Upper Cane Creek Restoration Project. This project involves the restoration and enhancement of approximately 6,700 linear feet of stream on Commissary Branch and the Right Fork of Cane Creek. Additionally, approximately 4,839 feet of County Road 208 will be relocated away from the restored stream channel to an adjacent hillside as part of this project.

We have reviewed the BA for the Indiana bat, Virginia big-eared bat, Gray bat, and White-haired goldenrod. Based on the submitted information, we concur with the no effect finding for the white-haired goldenrod (*Solidago albopilosa*) and the not likely to adversely affect determination for the Indiana bat (*Myotis sodalis*), gray bat (*Myotis grisescens*) and Virginia big-eared bat (*Corynorhinus townsendii virginianus*). We also concur with the no effect finding on critical habitat for the Indiana bat and Virginia big-eared bat. Critical habitat has not been designated for the gray bat or white-haired goldenrod.

Based on these determinations and our concurrences with them, we believe that the requirements of section 7 have been fulfilled as it relates to federally listed species listed in the BA. Obligations under section 7 must be reconsidered, however, if: (1) new information reveals that the proposed project may affect listed species or proposed critical habitat in a manner or to an extent not previously considered, (2) the proposed project is subsequently modified to include activities which were not considered during this consultation, or (3) new species are listed or critical habitat designated that might be affected by the proposed project.

If you need additional assistance in determining if a proposed project may impact a federally listed species, we recommend that you contact us for further assistance. Thank you for the opportunity to comment on this proposed action. If you have any questions regarding the information which we have provided, please contact Jennifer Garland at (502)695-0468 extension 115.

Sincerely,

Virgil Lee Andrews, Jr.

Virgil Lee Andrews, Jr.
Field Supervisor

APPENDIX B

STATE HISTORIC PRESERVATION OFFICE

CONCURRENCE LETTER

Steven L. Beshear
Governor

The State Historic Preservation Office
300 Washington Street
Frankfort, Kentucky 40601
Phone (502) 564-7005
Fax (502) 564-5820
www.kentucky.gov

Marcheta Sparrow
Secretary

Donna M. Neary
Executive Director and
State Historic Preservation Officer

January 28, 2008

Ms. Christy Mower
5088 West Washington Street
2nd Floor
Charleston WV 25313

Re: Upper Cane Creek, Menifee County, Kentucky

Dear Mr. Mower:

Thank you for your letter concerning the above referenced project. Our reviews indicate that the proposed project take place in previously disturbed areas. In accordance with 36 CFR Part 800.4(d) of the Advisory Council's revised regulations our finding is that there will be no Historic Properties Affected within the undertaking's area of potential impact. Therefore, we have no further comment, and the Agency Official's responsibility to consult with the State Historic Preservation Officer under the Section 106 review process for archaeology is fulfilled. If the project boundaries change, this office should be consulted to determine the nature and extent of additional documentation that may be needed.

Should you have any questions, feel free to contact Lori Stahlgren of my staff at (502) 564-7005, extension 151.

Sincerely,

Donna M. Neary

Donna M. Neary, Director
Kentucky Heritage Council and
State Historic Preservation Officer

LCS:lcs

APPENDIX C

EASTERN KENTUCKY STREAM ASSESSMENT PROTOCOL SHEETS

PRE-E ISTING EIU VALUES

PROPOSED IMPACT SITE

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach RUT1 of Right Fork of Upper Cane Creek - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.55	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	10	no units	
2. Embeddedness	14	no units	
3. Velocity/Depth Regime	1	no units	
4. Sediment Deposition	10	no units	
5. Channel Flow Status	1	no units	
6. Channel Alteration	10	no units	
7. Freq. Of Riffles (bends)	14	no units	
8. Bank stability (both combined)	13	no units	
9. Veg. Protection (both combined)	13	no units	
10. Riparian Width (both combined)	13	no units	
Total Habitat Score	99	no units	Subindex
Habitat Integrity Index			0.10
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	142	microMHOs	1.00

PROPOSED MITIGATION SITES

RIGHT FOR OF UPPER CANE CREE
AND ITS ASSOCIATED TRIBUTARIES

Project ID	Upper Cane Stream Enhancement & Restoration Project
Stream/Reach	Right Fork of Upper Cane Creek - Reaches 1&2 - Pre-existing
Assessment Objectives	Create an Ecological Life by implementing stream restoration and enhancement techniques

EII	Model
0.78	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.77	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	16	no units	
2. Embeddedness	11	no units	
3. Velocity/Depth Regime	15	no units	
4. Sediment Deposition	15	no units	
5. Channel Flow Status	14	no units	
6. Channel Alteration	13	no units	
7. Freq. Of Riffles (bends)	11	no units	
8. Bank stability (both combined)	18	no units	
9. Veg. Protection (both combined)	18	no units	
10. Riparian Width (both combined)	11	no units	
Total Habitat Score	142	no units	
Habitat Integrity Index			0.53
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	21	# of taxa sampled	
12. Family EPT Richness	10	# of EPT species sampled	
13. % Ephemeroptera	35	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	5	% Midges & Worms (0-100)	
15. mFBI	4.1	no units	
Macroinvertebrate Bioassessment	67.43	no units	0.81
Conductivity	142	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach Right Fork of Upper Cane Creek - Reaches 3&4 - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.68	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.59	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	16	no units	
2. Embeddedness	11	no units	
3. Velocity/Depth Regime	14	no units	
4. Sediment Deposition	11	no units	
5. Channel Flow Status	14	no units	
6. Channel Alteration	15	no units	
7. Freq. Of Riffles (bends)	14	no units	
8. Bank stability (both combined)	14	no units	
9. Veg. Protection (both combined)	14	no units	
10. Riparian Width (both combined)	10	no units	
Total Habitat Score	133	no units	Subindex
Habitat Integrity Index			0.43
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	24	# of taxa sampled	
12. Family EPT Richness	12	# of EPT species sampled	
13. % Ephemeroptera	33	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	3	% Midges & Worms (0-100)	
15. mFBI	3.7	no units	
Macroinvertebrate Bioassessment	72.01	no units	0.87
Conductivity	240	microMHOs	0.74

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach RUT1 of Right Fork of Upper Cane Creek - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.55	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	10	no units	
2. Embeddedness	14	no units	
3. Velocity/Depth Regime	1	no units	
4. Sediment Deposition	10	no units	
5. Channel Flow Status	1	no units	
6. Channel Alteration	10	no units	
7. Freq. Of Riffles (bends)	14	no units	
8. Bank stability (both combined)	13	no units	
9. Veg. Protection (both combined)	13	no units	
10. Riparian Width (both combined)	13	no units	
Total Habitat Score	99	no units	Subindex
Habitat Integrity Index			0.10
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	142	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach LUT1 of Right Fork of Upper Cane Creek - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.50	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	11	no units	
2. Embeddedness	15	no units	
3. Velocity/Depth Regime	1	no units	
4. Sediment Deposition	10	no units	
5. Channel Flow Status	1	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	14	no units	
8. Bank stability (both combined)	16	no units	
9. Veg. Protection (both combined)	14	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	116	no units	Subindex
Habitat Integrity Index			0.26
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	240	microMHOs	0.74

COMMISSARY BRANCH

AND ITS ASSOCIATED TRIBUTARIES

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach Commissary Branch - Reaches 1&2 - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.79	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.69	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	18	no units	
2. Embeddedness	13	no units	
3. Velocity/Depth Regime	13	no units	
4. Sediment Deposition	8	no units	
5. Channel Flow Status	9	no units	
6. Channel Alteration	15	no units	
7. Freq. Of Riffles (bends)	13	no units	
8. Bank stability (both combined)	10	no units	
9. Veg. Protection (both combined)	14	no units	
10. Riparian Width (both combined)	14	no units	
Total Habitat Score	127	no units	
Habitat Integrity Index			0.37
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	26	# of taxa sampled	
12. Family EPT Richness	14	# of EPT species sampled	
13. % Ephemeroptera	59	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	4	% Midges & Worms (0-100)	
15. mFBI	3.7	no units	
Macroinvertebrate Bioassessment	82.23	no units	0.99
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach Commissary Branch - Reach 3 - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.76	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.69	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	13	no units	
2. Embeddedness	12	no units	
3. Velocity/Depth Regime	11	no units	
4. Sediment Deposition	11	no units	
5. Channel Flow Status	8	no units	
6. Channel Alteration	15	no units	
7. Freq. Of Riffles (bends)	8	no units	
8. Bank stability (both combined)	15	no units	
9. Veg. Protection (both combined)	18	no units	
10. Riparian Width (both combined)	16	no units	
Total Habitat Score	127	no units	Subindex
Habitat Integrity Index			0.37
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	26	# of taxa sampled	
12. Family EPT Richness	14	# of EPT species sampled	
13. % Ephemeroptera	36	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	5	% Midges & Worms (0-100)	
15. mFBI	3.7	no units	
Macroinvertebrate Bioassessment	75.49	no units	0.91
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project
Stream/Reach RUT1 of Commissary Branch - Pre-existing
Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.55	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	7	no units	
2. Embeddedness	15	no units	
3. Velocity/Depth Regime	1	no units	
4. Sediment Deposition	15	no units	
5. Channel Flow Status	1	no units	
6. Channel Alteration	15	no units	
7. Freq. Of Riffles (bends)	2	no units	
8. Bank stability (both combined)	6	no units	
9. Veg. Protection (both combined)	6	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	86	no units	
Habitat Integrity Index			0.10
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	120	microMHOs	1.00

Project ID	Upper Cane Stream Enhancement & Restoration Project
Stream/Reach	RUT2 of Commissary Branch - Pre-existing
Assessment Objectives	Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.55	Ecological Integrity Index (Habitat Integrity Conductivity)

Enter quantitative or categorical measure from Field Data Sheet in shaded cells

Variables	Measure	Units	Subindex
RBP Habitat Parameters			
1. Epifaunal Substrate	12	no units	
2. Embeddedness	10	no units	
3. Velocity/Depth Regime	1	no units	
4. Sediment Deposition	10	no units	
5. Channel Flow Status	15	no units	
6. Channel Alteration	5	no units	
7. Freq. Of Riffles (bends)	5	no units	
8. Bank stability (both combined)	10	no units	
9. Veg. Protection (both combined)	2	no units	
10. Riparian Width (both combined)	10	no units	
Total Habitat Score	80	no units	
Habitat Integrity Index			0.10
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach LUT1 of Commissary Branch - Pre-existing

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.58	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	6	no units	
2. Embeddedness	10	no units	
3. Velocity/Depth Regime	1	no units	
4. Sediment Deposition	10	no units	
5. Channel Flow Status	1	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	12	no units	
8. Bank stability (both combined)	16	no units	
9. Veg. Protection (both combined)	16	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	106	no units	
Habitat Integrity Index			0.16
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	120	microMHOs	1.00

POST CONSTRUCTION PREDICTED EIU VALUES

UPPER CANE CREE
AND ITS ASSOCIATED TRIBUTARIES

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach Right Fork of Upper Cane Creek - Reaches 1&2 - Predicted

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.92	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.98	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	17	no units	
2. Embeddedness	16	no units	
3. Velocity/Depth Regime	16	no units	
4. Sediment Deposition	16	no units	
5. Channel Flow Status	16	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	16	no units	
8. Bank stability (both combined)	18	no units	
9. Veg. Protection (both combined)	18	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	167	no units	
Habitat Integrity Index			0.95
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	21	# of taxa sampled	
12. Family EPT Richness	10	# of EPT species sampled	
13. % Ephemeroptera	35	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	5	% Midges & Worms (0-100)	
15. mFBI	4.1	no units	
Macroinvertebrate Bioassessment	67.43	no units	0.81
Conductivity	142	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach Right Fork of Upper Cane Creek - Reaches 3&4 - Predicted

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.87	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.87	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	17	no units	
2. Embeddedness	17	no units	
3. Velocity/Depth Regime	16	no units	
4. Sediment Deposition	18	no units	
5. Channel Flow Status	16	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	16	no units	
8. Bank stability (both combined)	18	no units	
9. Veg. Protection (both combined)	18	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	170	no units	Subindex
Habitat Integrity Index			1.00
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	24	# of taxa sampled	
12. Family EPT Richness	12	# of EPT species sampled	
13. % Ephemeroptera	33	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	3	% Midges & Worms (0-100)	
15. mFBI	3.7	no units	
Macroinvertebrate Bioassessment	72.01	no units	0.87
Conductivity	240	microMHOs	0.74

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach RUT1 of Right Fork of Upper Cane Creek - Predicted

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.72	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	15	no units	
2. Embeddedness	14	no units	
3. Velocity/Depth Regime	12	no units	
4. Sediment Deposition	15	no units	
5. Channel Flow Status	6	no units	
6. Channel Alteration	15	no units	
7. Freq. Of Riffles (bends)	14	no units	
8. Bank stability (both combined)	16	no units	
9. Veg. Protection (both combined)	13	no units	
10. Riparian Width (both combined)	13	no units	
Total Habitat Score	133	no units	Subindex
Habitat Integrity Index			0.43
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	142	microMHOs	1.00

Project ID	Upper Cane Stream Enhancement & Restoration Project
Stream/Reach	LUT1 of Right Fork of Upper Cane Creek - Predicted
Assessment Objectives	Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.62	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	15	no units	
2. Embeddedness	15	no units	
3. Velocity/Depth Regime	12	no units	
4. Sediment Deposition	14	no units	
5. Channel Flow Status	5	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	14	no units	
8. Bank stability (both combined)	16	no units	
9. Veg. Protection (both combined)	14	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	139	no units	Subindex
Habitat Integrity Index			0.49
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	240	microMHOs	0.74

COMMISSARY BRANCH
AND ITS ASSOCIATED TRIBUTARIES

Project ID	Upper Cane Stream Enhancement & Restoration Project
Stream/Reach	Commissary Branch - Reaches 1&2 - Predicted
Assessment Objectives	Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.94	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.91	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	18	no units	
2. Embeddedness	16	no units	
3. Velocity/Depth Regime	13	no units	
4. Sediment Deposition	16	no units	
5. Channel Flow Status	13	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	13	no units	
8. Bank stability (both combined)	18	no units	
9. Veg. Protection (both combined)	18	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	159	no units	
Habitat Integrity Index			0.82
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	26	# of taxa sampled	
12. Family EPT Richness	14	# of EPT species sampled	
13. % Ephemeroptera	59	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	4	% Midges & Worms (0-100)	
15. mFBI	3.7	no units	
Macroinvertebrate Bioassessment	82.23	no units	0.99
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach Commissary Branch - Reach 3 - Predicted

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
0.90	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.89	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	16	no units	
2. Embeddedness	16	no units	
3. Velocity/Depth Regime	13	no units	
4. Sediment Deposition	16	no units	
5. Channel Flow Status	13	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	13	no units	
8. Bank stability (both combined)	18	no units	
9. Veg. Protection (both combined)	18	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	157	no units	
Habitat Integrity Index			0.78
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness	26	# of taxa sampled	
12. Family EPT Richness	14	# of EPT species sampled	
13. % Ephemeroptera	36	% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta	5	% Midges & Worms (0-100)	
15. mFBI	3.7	no units	
Macroinvertebrate Bioassessment	75.49	no units	0.91
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project
Stream/Reach RUT1 Commissary Branch - Predicted
Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.68	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	Subindex
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	14	no units	
2. Embeddedness	16	no units	
3. Velocity/Depth Regime	3	no units	
4. Sediment Deposition	16	no units	
5. Channel Flow Status	1	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	12	no units	
8. Bank stability (both combined)	18	no units	
9. Veg. Protection (both combined)	12	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	126	no units	
Habitat Integrity Index			0.36
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach RUT2 of Commissary Branch - Predicted

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.78	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	15	no units	
2. Embeddedness	15	no units	
3. Velocity/Depth Regime	12	no units	
4. Sediment Deposition	15	no units	
5. Channel Flow Status	15	no units	
6. Channel Alteration	15	no units	
7. Freq. Of Riffles (bends)	15	no units	
8. Bank stability (both combined)	16	no units	
9. Veg. Protection (both combined)	12	no units	
10. Riparian Width (both combined)	14	no units	
Total Habitat Score	144	no units	Subindex
Habitat Integrity Index			0.57
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	120	microMHOs	1.00

Project ID Upper Cane Stream Enhancement & Restoration Project

Stream/Reach LUT1 of Commissary Branch - Predicted

Assessment Objectives Create an Ecological Lift by implementing stream restoration & enhancement techniques

EII	Model
NA	Ecological Integrity Index (MBI Habitat Integrity Conductivity)
0.72	Ecological Integrity Index (Habitat Integrity Conductivity)

Variables	Measure	Units	
Enter quantitative or categorical measure from Field Data Sheet in shaded cells			
RBP Habitat Parameters			
1. Epifaunal Substrate	15	no units	
2. Embeddedness	12	no units	
3. Velocity/Depth Regime	10	no units	
4. Sediment Deposition	14	no units	
5. Channel Flow Status	5	no units	
6. Channel Alteration	16	no units	
7. Freq. Of Riffles (bends)	12	no units	
8. Bank stability (both combined)	16	no units	
9. Veg. Protection (both combined)	16	no units	
10. Riparian Width (both combined)	18	no units	
Total Habitat Score	134	no units	Subindex
Habitat Integrity Index			0.44
Macroinvertebrate Data - Family Level (All Habitats)			
11. Family Taxa Richness		# of taxa sampled	
12. Family EPT Richness		# of EPT species sampled	
13. % Ephemeroptera		% Mayflies (0-100)	
14. % Chironomidae & Oligochaeta		% Midges & Worms (0-100)	
15. mFBI		no units	
Macroinvertebrate Bioassessment	NA	no units	NA
Conductivity	120	microMHOs	1.00

GAINS OR LOSSES

PROPOSED IMPACT AREA

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: RUT1 of Right Fork of Upper Cane Creek - Road Crossing

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.55	47	26
Postproject	0.00	47	0

Net Loss =	**-26**
Net Gain =	**NA****

PROPOSED MITIGATION AREAS

RIGHT FOR OF UPPER CANE CREE
AND ITS ASSOCIATED TRIBUTARIES

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: Right Fork of Upper Cane Creek - Reaches 1&2

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.78	1740	1361
Postproject	0.92	1696	1562

Net Loss =	**NA**
Net Gain =	**201**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: Right Fork of Upper Cane Creek - Reaches 3&4

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.68	1565	1064
Postproject	0.87	1545	1344

Net Loss =	**NA**
Net Gain =	**280**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: RUT1 of Right Fork of Upper Cane Creek

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.55	45	25
Postproject	0.72	45	32

Net Loss =	**NA**
Net Gain =	**7**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: LUT1 of Right Fork of Upper Cane Creek

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.50	43	22
Postproject	0.62	43	27

Net Loss =	**NA**
Net Gain =	**5**

COMMISSARY BRANCH
AND ITS ASSOCIATED TRIBUTARIES

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: Commissary Branch - Reaches 1&2

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.79	2372	1,867
Postproject	0.94	2427	2,271

Net Loss =	**NA**
Net Gain =	**405**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: Commissary Branch - Reach 3

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.76	240	182
Postproject	0.90	240	215

Net Loss =	**NA**
Net Gain =	**33**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: RUT1 of Commissary Branch

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.55	21	12
Postproject	0.68	21	14

Net Loss =	**NA**
Net Gain =	**2**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: RUT2 of Commissary Branch

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.55	28	15
Postproject	0.78	28	22

Net Loss =	**NA**
Net Gain =	**7**

Project ID: Upper Cane Stream Enhancement & Restoration Project

Stream/Reach: LUT1 of Commissary Branch

Assessment Objectives: Create an Ecological Life by implementing stream restoration & enhancement techniques

	EII	Project Length	EIU
Preproject	0.58	38	22
Postproject	0.72	38	27

Net Loss =	**NA**
Net Gain =	**5**

APPENDIX D

PRELIMINARY JURIDICTIONAL DETERMINATION

PRELIMINARY JURISDICTIONAL DETERMINATION FORM

BACKGROUND INFORMATION

A. REPORT COMPLETION DATE FOR PRELIMINARY JURISDICTIONAL DETERMINATION (JD):

B. NAME AND ADDRESS OF PERSON REQUESTING PRELIMINARY JD:
Kentucky Department of Fish & Wildlife Resources

C. DISTRICT OFFICE, FILE NAME, AND NUMBER: Louisville Office,

D. PROJECT LOCATION(S) AND BACKGROUND INFORMATION:
The project is located in the headwaters of Upper Cane Creek at the end of Pumpkin Hollow Road, 6.6 miles northeast of Stanton, KY, in Menifee County. Directions: Take 11/15 east out of Stanton, left onto Rt 1184, right onto Rt 615, left onto Rt 599, then right onto Pumpkin Hollow Road. The property is owned by several individuals who bought the land as a group to be used for hunting. See Table 1 for additional summary information.

The project is located on the Frenchburg Quad having coordinates as described below:
Head of Right Fork: 37° 54' 40.7" N, 83° 44' 32.7" W
Head of Commissary Branch: 37° 54' 22.6" N, 83° 43' 55.3" W
Downstream end of Project: 37° 54' 8.6" N, 83° 44' 16.7" W

(USE THE ATTACHED TABLE TO DOCUMENT MULTIPLE WATERBODIES AT DIFFERENT SITES)

State: KY County/parish/borough: Menifee City: Stanton
Center coordinates of site (lat/long in degree decimal format): Lat. 37.905055° N, Long. 83.737218° W
Universal Transverse Mercator: 259333.7 N 4198599.6E
Name of nearest waterbody: Ohio River, Traditional Navigable Water

Identify (estimate) amount of waters in the review area:
Non-wetland waters: 6,083 linear feet: 8.2 average width (ft) and/or 1.2 (stream) acres.
Cowardin Class: NA
Stream Flow: Intermittent & ephemeral
Wetlands: NA acres.
Cowardin Class: NA

Name of any water bodies on the site that have been identified as Section 10 waters:
Tidal: NA
Non-Tidal: NA

E. REVIEW PERFORMED FOR SITE EVALUATION (CHECK ALL THAT APPLY):

☐ Office (Desk) Determination. Date:

☐ Field Determination. Date(s):

1. The Corps of Engineers believes that there may be jurisdictional waters of the United States on the subject site, and the permit applicant or other affected party who requested this preliminary JD is hereby advised of his or her option to request and obtain an approved jurisdictional determination (JD) for that site. Nevertheless, the permit applicant or other person who requested this preliminary JD has declined to exercise the option to obtain an approved JD in this instance and at this time.

2. In any circumstance where a permit applicant obtains an individual permit, or a Nationwide General Permit (NWP) or other general permit verification requiring "pre-construction notification" (PCN), or requests verification for a non-reporting NWP or other general permit, and the permit applicant has not requested an approved JD for the activity, the permit applicant is hereby made aware of the following: (1) the permit applicant has elected to seek a permit authorization based on a preliminary JD, which does not make an official determination of jurisdictional waters; (2) that the applicant has the option to request an approved JD before accepting the terms and conditions of the permit authorization, and that basing a permit authorization on an approved JD could possibly result in less compensatory mitigation being required or different special conditions; (3) that the applicant has the right to request an individual permit rather than accepting the terms and conditions of the NWP or other general permit authorization; (4) that the applicant can accept a permit authorization and thereby agree to comply with all the terms and conditions of that permit, including whatever mitigation requirements the Corps has determined to be necessary; (5) that undertaking any activity in reliance upon the subject permit authorization without requesting an approved JD constitutes the applicant's acceptance of the use of the preliminary JD, but that either form of JD will be processed as soon as is practicable; (6) accepting a permit authorization (e.g., signing a proffered individual permit) or undertaking any activity in reliance on any form of Corps permit authorization based on a preliminary JD constitutes agreement that all wetlands and other water bodies on the site affected in any way by that activity are jurisdictional waters of the United States, and precludes any challenge to such jurisdiction in any administrative or judicial compliance or enforcement action, or in any administrative appeal or in any Federal court; and (7) whether the applicant elects to use either an approved JD or a preliminary JD, that JD will be processed as soon as is practicable. Further, an approved JD, a proffered individual permit (and all terms and conditions contained therein), or individual permit denial can be administratively appealed pursuant to 33 C.F.R. Part 331, and that in any administrative appeal, jurisdictional issues can be raised (see 33

C.F.R. 331.5(a)(2)). If, during that administrative appeal, it becomes necessary to make an official determination whether CWA jurisdiction exists over a site, or to provide an official delineation of jurisdictional waters on the site, the Corps will provide an approved JD to accomplish that result, as soon as is practicable. This preliminary JD finds that there *"may be"* waters of the United States on the subject project site, and identifies all aquatic features on the site that could be affected by the proposed activity, based on the following information:

**SUPPORTING DATA. Data reviewed for preliminary JD (check all that apply - **checked items should be included in case file and, where checked and requested, appropriately reference sources below):

☒ Maps, plans, plots or plat submitted by or on behalf of the applicant/consultant: Michael Baker Jr., Incorporated

☒ Data sheets prepared/submitted by or on behalf of the applicant/consultant.

☐ Office concurs with data sheets/delineation report.

☐ Office does not concur with data sheets/delineation report.

☐ Data sheets prepared by the Corps: .

☐ Corps navigable waters' study: .

☐ U.S. Geological Survey Hydrologic Atlas: .

☐ USGS NHD data.

☒ USGS 8 and 12 digit HUC maps.

☒ U.S. Geological Survey map(s). Cite scale & quad name: Scale 1:1000. Frenchburg and Means Quad.

☒ USDA Natural Resources Conservation Service Soil Survey. Citation: United States Department of Agriculture (USDA). 2007. Soil Survey of Menifee and Rowan Counties, West Virginia. United States Department of Agriculture, Soil Conservation Service, Washington DC.

☐ National wetlands inventory map(s). Cite name: .

☐ State/Local wetland inventory map(s): .

☐ FEMA/FIRM maps: .

☐ 100-year Floodplain Elevation is: (National Geodectic Vertical Datum of 1929)

☒ Photographs: ☒ Aerial (Name & Date): 2006, NAIP .

or ☒ Other (Name & Date):LIDAR, December 2007.

☐ Previous determination(s). File no. and date of response letter: .

☐ Other information (please specify): .

<u>IMPORTANT NOTE: The information recorded on this form has not necessarily been verified by the Corps and should not be relied upon for later jurisdictional determinations.</u>

__________________________	__________________________
Signature and date of Regulatory Project Manager (REQUIRED)	Signature and date of person requesting preliminary JD (REQUIRED, unless obtaining the signature is impracticable)

Table 1. Summary information for Item D in Background Information.

Site number	Latitude	Longitude	Cowardin Class	Estimated amount of aquatic resource in review area	Class of aquatic resource
1. Right Fork of Upper Cane Creek	37° 54' 40.7" N	83° 44' 32.7" W	NA	3,241 linear feet	non-section 10 – non-wetland
2. Right Unnamed Tributary of Right Fork of Upper Cane Creek	37° 54' 23.3" N	83° 44' 21.6" W	NA	45 linear feet (enhancement at mouth) 47 linear feet (road crossing)	non-section 10 – non-wetland
3. Left Unnamed Tributary of Right Fork of Upper Cane Creek	37° 54' 29.3" N	83° 44' 33.9" W	NA	43 linear feet	non-section 10 – non-wetland
4. Commissary Branch	37° 54' 22.6" N	83° 43' 55.3" W	NA	2,667 linear feet	non-section 10 – non-wetland
5. 1st Right Unnamed Tributary of Commissary Branch	37° 54' 6.5" N	83° 43' 58.1" W	NA	21 linear feet	non-section 10 – non-wetland
6. 2nd Right Unnamed Tributary of Commissary Branch	37° 54' 19.6" N	83° 43' 50.5" W	NA	28 linear feet	non-section 10 – non-wetland
7. Left Unnamed Tributary of Right Fork of Upper Cane Creek	37° 54' 21.8" N	83° 43' 0.8" W	NA	38 linear feet	non-section 10 – non-wetland

APPENDIX E

EASEMENT DOCUMENTS

STREAM EASEMENT

606/765-3512

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JUL 6 9 45 AM '05

DEED OF CONSERVATION EASEMENT

THIS DEED OF CONSERVATION EASEMENT is entered into by and between Chip Culton, Dale Gough, Richard Shadwick, Randy Phipps, Dennis Phipps and Ron Lutrell (hereinafter "Grantors") and the Department of Fish and Wildlife Resources, for and on behalf of the Commonwealth of Kentucky (hereinafter "Grantee").

WITNESS THAT:

WHEREAS, the Grantors are the administrator of certain real property (hereinafter "Project Area") located in Menifee County, Kentucky, and more particularly described in the "Project Area Description" attached hereto and incorporated herein as Exhibit A; and

WHEREAS, the Project Area will be improved by – restoring and enhancing Right Fork Cane Creek and Commissary Branch to include moving the road outside of the stream channel, grade control, reconstructing a new channel where deemed necessary, bank stabilization and tree planting as needed; and

WHEREAS, the Grantee is a governmental body empowered to hold an interest in real property under the laws of the Commonwealth of Kentucky and the United States and, therefore, qualifies as a holder pursuant to KRS 382.800; and

WHEREAS, KRS 382.800 through KRS 382.860 permits the creation of conservation easements for the purposes of, inter alia, retaining land or water areas predominantly in their natural, scenic, open or wooded condition or as suitable habitat for fish, plants, or wildlife; and

NOW, THEREFORE, in consideration of the mutual covenants contained herein; and further, pursuant to KRS 382.800 through 382.860, Grantors do hereby convey to Grantee a Conservation Easement (hereinafter "Easement") in perpetuity over the Project Area to be held for the benefit of the people of the Commonwealth of Kentucky and consisting of the following:

(1) The Project Area shall be maintained in perpetuity for the following purpose:

stream habitat

(2) Grantee shall manage the Project Area in strict accordance with:

(a) KRS Chapter 150

(b) KRS 382.800 through 382.860, and

(c) the detailed channel design plan pertaining to the Project Area which has been generated by the Grantee.

(3) The Grantee has the right of visual access to and view of the Project Area in its natural, scenic, open and undisturbed condition.

(4) The Grantee has the right to enter the Project Area, in a reasonable manner and at reasonable times, for the purposes of inspecting same to determine compliance with this Easement.

(5) There shall be no removal, destruction, cutting, trimming, mowing, alteration, or spraying with biocides of any vegetation, nor any disturbance or change in the natural habitat within the Project Area in any manner unless addressed in the final design plan or specifically authorized by the Grantee.

(6) There shall be no planting or introduction of any species of vegetation within the Project Area unless addressed in the final design plan or specifically authorized by the Grantee.

(7) There shall be no harvesting of timber within the Project Area unless addressed in the final design plan or specifically authorized by the Grantee.

(8) There shall be no commercial or industrial activity undertaken or allowed within the Project Area, except for access though the site. In such case, the stream bed shall not be used as a road.

(9) Grantor shall be allowed to remove trash and debris from the Project Area.

(10) There shall be no filling, excavation, or dredging, within the Project Area. Except the landowner may cross the stream channel perpendicularly (90 degrees) in order to tap into existing gas wells.

(11) There shall be no mining or drilling within the Project Area. Except the landowner may tap into existing gas wells.

(12) There shall be no removal of topsoil, sand, gravel, rock, minerals or other materials within the Project Area.

(13) There shall be no dumping of ashes, trash, garbage, or any other material within the Project Area.

(14) There shall be no changing of the topography within the Project Area in any manner.

(15) There shall be no construction or placing of temporary or permanent buildings, mobile homes, advertising signs, billboards, or other advertising material, or other structures within the Project Area.

(16) Except with the written consent of the Grantee, there shall be no building of new roads, trails, or other rights of way within the Project Area. Except access to upper Commissary Branch is permitted. Existing trails, stream crossings and roads may be maintained by reasonable means consistent with the purposes of this Easement.

(17) There shall be no introduction of nonindigenous wildlife into the Property area without the written consent of the Grantee. (Plants are covered in paragraph 6.)

(18) There shall be no damming, dredging or construction in any free-flowing water body, nor construction of any weirs, groins, or dikes in any wetlands, or any manipulation or alteration of natural water courses, fresh water lake or pond shores, marshes, wetlands, or other water bodies nor any activities or uses detrimental to water purity within the Project Area.

(19) There shall be no operation of mechanical or motorized vehicles within the stream channel, not including designated crossings. Mechanical or motorized vehicles shall cross perpendicular to the channel, as opposed to, driving the vehicle up and down the length of the stream.

(20) Any use of the Project Area or any activity thereon which, in the opinion of the Grantee, is or may become inconsistent with the purpose of this Easement, which is the preservation of the area in its natural and undisturbed condition for the purposes set out in KRS 382.800(1) and the management and protection of its environmental systems, is prohibited.

(21) In the event of a violation of any term, condition, or restriction contained in this Easement, the Grantee may immediately enforce any of the remedies including but not limited to those set forth in KRS 382.990. Any failure by the Grantee to avail itself of these remedies shall not be deemed to be a waiver or forfeiture of the right to enforce any term, condition, covenant of purpose of this Easement.

(22) This Easement shall be a burden upon and shall run with the Project Area in perpetuity and shall bind the Grantor, its successors and assigns forever.

(23) The rights herein granted shall be in addition to, and not in limitation of, any other rights and remedies available to the Grantee for protection of the Project Area.

(24) In the event that the project is not implemented, this Easement shall become null and void.

TO HAVE AND TO HOLD this Conservation Easement together with all the appurtenances and privileges belonging or in any way pertaining thereto, either in law or in equity, for the proper use and benefit of the Grantee, its successors and assigns, forever.

IN WITNESS WHEREOF, , Grantor, has executed this Deed of Conservation Easement this 27th day of June, 2005.

____
Authorized Representative of Grantors

____

____

____

____

____

STATE OF KENTUCKY

COUNTY OF Jessamine

I, the undersigned, a notary public duly authorized in the county and state aforesaid, do hereby certify that on this day ~~June 27, 2005~~ Randy Phipps, Eugene Aulton, Dimmit Phipps, Ronald Luttrell & Dale Hough personally appeared before me and executed the foregoing instrument as ________ of ________, and acknowledged before me that he executed the same as such officer in the name of and for and on behalf of the said entity.

IN WITNESS WHEREOF, I have hereunto set my hand and official seal, this 27th day of June, 2005.

Deborah L. Phipps
NOTARY PUBLIC

My Commission Expires: May 19, 2009

IN WITNESS WEHREOF, THE KDFWR, Grantee, accepts this deed of conservation easement this 11th day of April, 2005.

[signature]
Authorized Representative of Grantee

STATE OF KENTUCKY

COUNTY OF Franklin

I, the undersigned, a notary public duly authorized in the county and state aforesaid, do hereby certify that on this day Jonathan Gassett personally appeared before me and executed the foregoing instrument as Interim Commissioner of KDFWR, and acknowledged before me that he executed the same as such officer in the name of and for and on behalf of the said entity.

IN WITNESS WHEREOF, I have hereunto set my hand and official seal, this 11th day of April, 2005.

IN WITNESS WHEREOF, I have hereunto set my hand and official seal, this 11th day of April, 2005.

Sharon R. Watkins (Sparrow)

NOTARY PUBLIC

My Commission Expires: August 5, 2007

THIS INSTRUMENT PREPARED BY: William F. Payson

KY Dept Fish + Wildlife Resources
1 Game Farm Rd
Frankfort Ky 40601

STATE OF KENTUCKY
COUNTY OF MENIFEE } Sct.

I, Jo Ann S. Curtis, Clerk of the County and State aforesaid, certify that the foregoing deed was on the 6 day of July 20 05, lodged for Record whereupon the same with the foregoing and this certificate have been duly recorded in my office. Given under my hand, this 6 day of July 2005

Clerk, Jo Ann Curtis

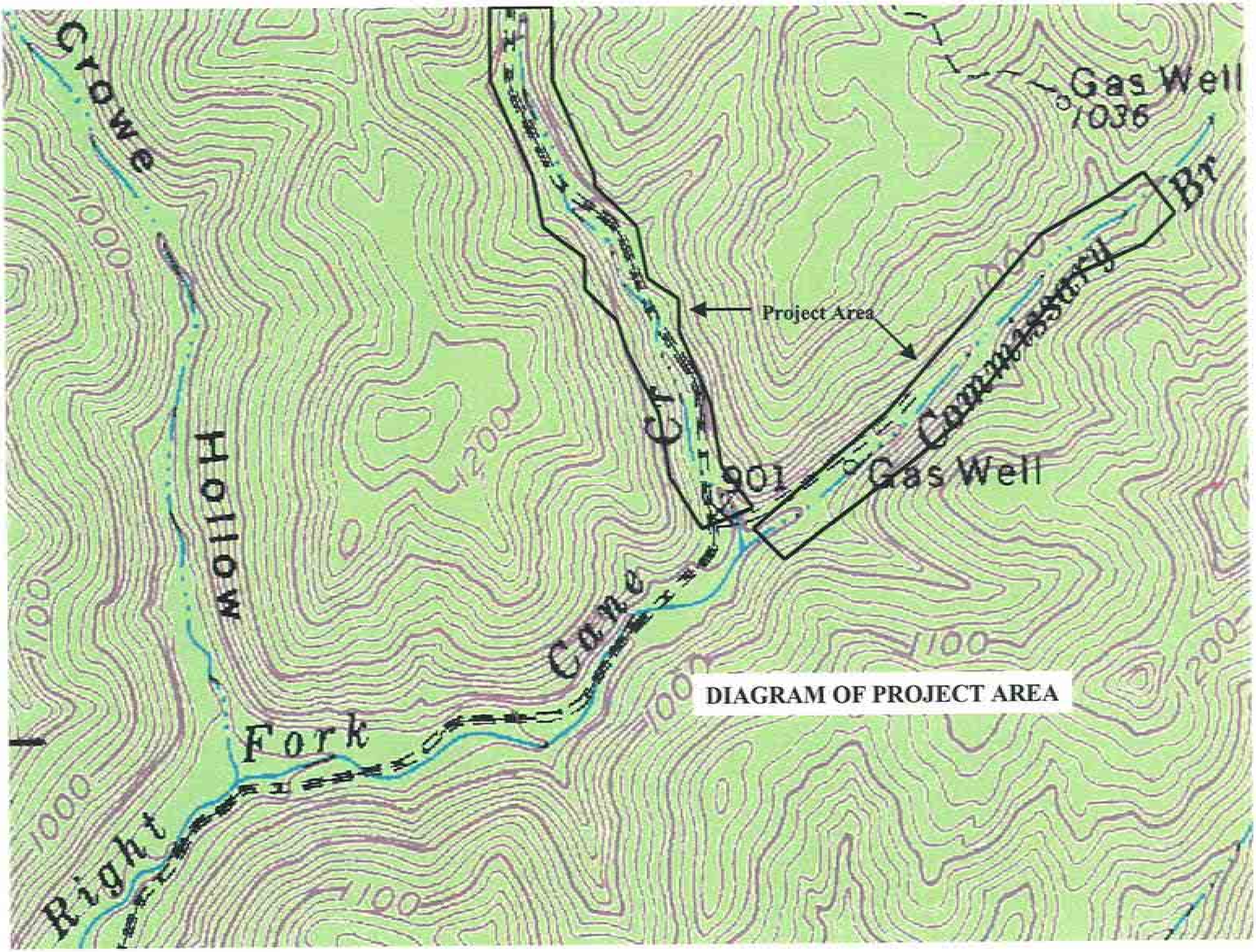
D.C.

EXIBIT "A"

Project Area Description

The "Project Area" referenced as the "Property" in the conservation easement is described as follows: The Project Area shall include the restored stream channel of Right Fork Cane Creek and Commissary Branch, and the adjacent land beginning at the toe of the restore stream bank extending fifty (50) feet along both sides of the channel of Right Fork and thirty (30) feet along both sides of Commissary Creek. The Project Area begins immediately upstream of the confluence of Right Fork Cane Creek and Commissary Branch, and ends 3,000 feet upstream on Commissary Branch and ends 4,635 feet upstream on Right Fork Cane Creek.

Refer to the attached diagram.


Crowe
Hollow
Gas Well
1036
Br
Commissary
Project Area
901
Gas Well
Cane
Fork
Right
DIAGRAM OF PROJECT AREA
1000
1100
1200

ROAD EASEMENT

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation

5088 West Washington Street
Charleston, West Virginia 25313

304.769.0821 Phone
304.769.0822 Fax

October 27, 2008

Mr. Randy Phipps
228 Murphy Lane
Nicholasville, KY 40356

Re: Road Easement for County Route 208
Upper Cane Creek of the Red River, Menifee County

Dear Mr. Phippps:

As directed, Baker has coordinated with the Kentucky Department of Fish & Wildlife Resources (KY Fish & Wildlife) and the Menifee County Courthouse in regards to the relocation of Menifee County Route 208. As discussed, all parties have agreed upon a variable easement along the relocated road, which will extend approximately around the construction limits of the new alignment. Attached is an exhibit showing the boundary of the easement or right-of-way of the new road alignment.

After review with your other partners, if you have decided you are comfortable with the easement document and its corresponding language, we are asking that both yourself and Chip Culton sign one copy of the document with a notary and forward the original back to us. We have included a self-addressed envelope for you to send the document back to Baker. If you are not comfortable with the document or need to discuss anything with us, please feel free to contact us or KY Fish & Wildlife at anytime. We have also included 2 extra copies of the information for you and Mr. Culton. If you need more copies, feel free to contact us.

Very truly yours,

MICHAEL BAKER JR., INC.

Christy M. Mower
Task Manager

for Patrick W. Fogarty, P.E., P.S.
Project Manager

Enclosure

c: File

RIGHT-OF-WAY EASEMENT

KNOW ALL MEN BY THESE PRESENTS:

That __Chip Culton, Dale Gough, Richard Shadwick, Randy Phipps, Dennis Phipps, and Ron Lutrell____, Grantor(s), having an address of _228 Murphy Lane Nicholasville, KY 40356, for and in good and valuable consideration acknowledged by the parties hereto. Grantee, Menifee County, having an address of __12 Main Street P.O. Box _105__, _Frenchburg, KY 40322____, does hereby grant, bargain, sell, transfer and convey unto the Grantee, its successors and assigns [if an individual, put in his/her heirs and assigns], a perpetual easement with the right to __County Road 208 maintenance__ over, across and through the land of the Grantor situated in Menifee County, State of Kentucky, said land being more particularly bounded and described on Exhibit A which is attached hereto and incorporated herein by reference. (Or, include description herein).

The subject easement shall be a variable right-of-way width based on the construction limits, which include an additional 5-foot buffer; resulting in a total right-of-way width ranging from 25 feet to 100 feet in width (Exhibit A). The location thereof shall be established by mutual consent between the parties hereto. Once the location of the easement has been initially established, the location thereof shall not be changed without the mutual consent of the parties hereto. The exact location of the easement is defined in the attached map.

To have and to hold said easement unto the Grantee, its successors and assigns [heirs and assigns], forever.

The Grantor further grants the Grantee the right of ingress and egress over the land of the said Grantor to and from said property described on Exhibit A in exercise of this easement.

It is understood by the partied hereto that this easement replaces the previous easement located __in the valleys of Commissary Branch and the Right Fork of Upper Cane Creek___________, in what ever manner previously granted to Grantee, whether by written documentation of by prescription, and said previous easement shall revert to the present surface owners. It is the intent of easement granted herein to replace said previous easement.

The Grantor reserves the right to fully use the subject premises except as such use may be inconsistent for the purposes granted herein. The Grantee agrees to maintain the easement in good repair so that no unreasonable damage will result from its use to the adjacent land of the Grantor.

IN WITNESS WHEREOF, the Grantor has executed this instrument on the 4th day of November, 2008.

Chip Culton
Randy Phipps

COMMONWEALTH OF KENTUCKY
COUNTY OF MENIFEE

Acknowledged, subscribed and sworn to before me this 4th day of November, 2008, by ______________________.

My Commission Expires: 04/02/12

Susan Lynn Collins
NOTARY

EXHIBIT A: EASEMENT AREA DESCRIPTION

The road easement area is defined as follows: the easement occurs along a county road (Pumpkin Hollow Rd, C.R. 208) extending from the southern property boundary to the northern property boundary of (parcel # 11-16 deed book 90 pg 542 and parcel # 11-15 deed book 92 pg 660). The easement area includes the 12-foot road width, designed by Michael Baker, Jr., Inc., in collaboration with Kentucky Department of Fish and Wildlife Resources (*see attached map*). Additionally, the road easement includes occasional turnoffs (less than 10-feet wide) for two-way traffic and the construction limits plus an additional 5-feet buffer. The easement area is shown more specifically on the attached map. The previous location of the road, located within the valleys of Commissary Branch and the Right Fork of Upper Cane Creek, is not included in the easement area and is property of the Grantors.

This exhibit is located at ____ within the Menifee County Courthouse.

BEGIN PROJECT
STA. 200+00.00
Co. Rt. 208
LIMITS OF CONSTRUCTION
ROAD EASEMENT
10 FT TURNOUT
6 FT TURNOUT
EXISTING CR 208 WILL BE TURNED INTO PRIVATE DRIVEWAY
END PROJECT
STA. 248+70.57
Co. Rt. 208
EXHIBIT A
RIGHT OF WAY EASEMENT
FOR PUMPKIN HOLLOW ROAD
COUNTY ROUTE 208
0 10 50 100 200 300
Baker
Michael Baker Jr., Inc. Charleston, W.Va.

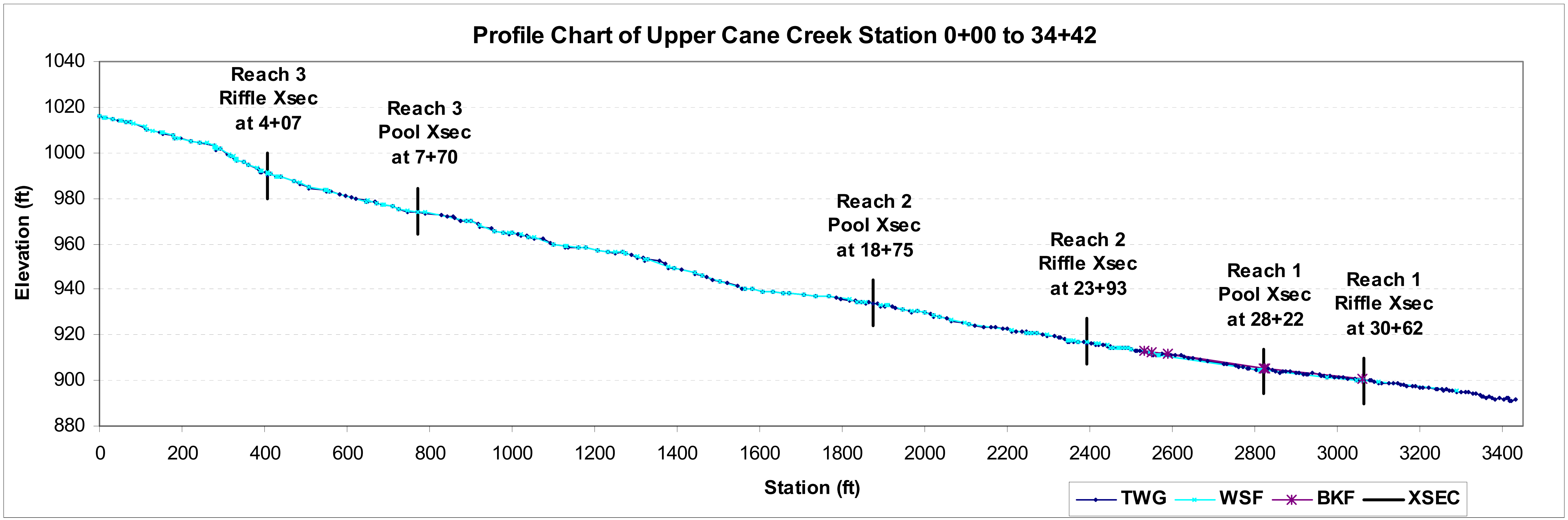
APPENDIX F

GEOMORPHOLOGY DATA

On-Site Existing Conditions Data For Right Fork of Upper Cane Creek

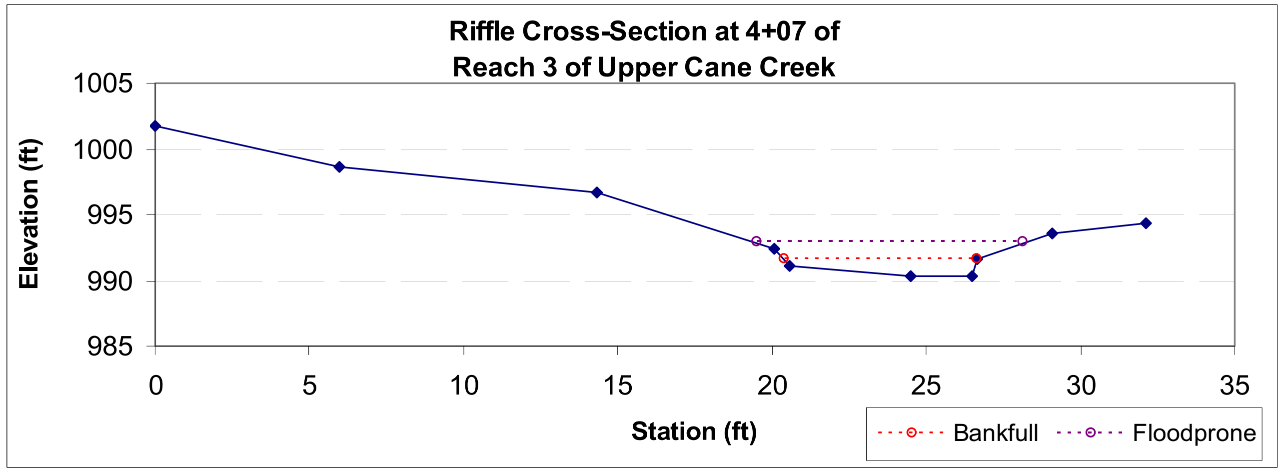
Parameter		Right Fork of Upper Cane Creek		
		Minimum	Maximum	Average
Rosgen Stream Type		----	----	F4b
Drainage Area (sq mi)		----	----	0.26
Reach Length Surveyed (ft)		----	----	3432.48
Dimension	Bankfull Width (ft)	6.3	8.2	7.5
	Bankfull Mean Depth (ft)	0.4	1.0	0.6
	Width/Depth Ratio	6.3	18.7	14.3
	Bankfull Area (sq ft)	3.4	6.2	4.4
	Bankfull Max Depth (ft)	0.6	1.3	0.9
	Width of Floodprone Area (ft)	8.6	10.3	9.4
	Entrenchement Ratio	1.2	1.4	1.3
	Max Pool Depth (ft)	0.5	1.1	0.8
	Ratio of Max Pool Depth to Bankfull Depth	0.9	1.8	1.3
	Pool Width (ft)	7.5	8.3	8.0
	Ratio of Pool Width to Bankfull Width	1.0	1.1	1.1
	Pool to Pool Spacing (ft)	17.9	448.8	127.2
	Ratio of Pool to Pool Spacing to Bankfull Width	2.4	60.1	17.0
	Bank Height Ratio	1.7	2.3	2.0
Pattern	Meander Length (ft)	----	----	----
	Meander Length Ratio	----	----	----
	Radius of Curvature (ft)	----	----	----
	Radius of Curvature Ratio	----	----	----
	Meander Belt Width (ft)	----	----	----
	Meander Width Ratio	----	----	----
	Sinuosity	----	----	1.21
Profile	Valley Slope (ft/ft)	----	----	0.0304
	WS Slope (ft/ft)	----	----	0.0367
	Channel Slope	----	----	0.0362
	Pool Slope (ft/ft)	0.0000	0.0164	0.0082
	Ratio of Pool Slope to WS Slope	0.0000	0.4469	0.2234

B channels have low to moderate sinuosity and typically do have meander geometry.

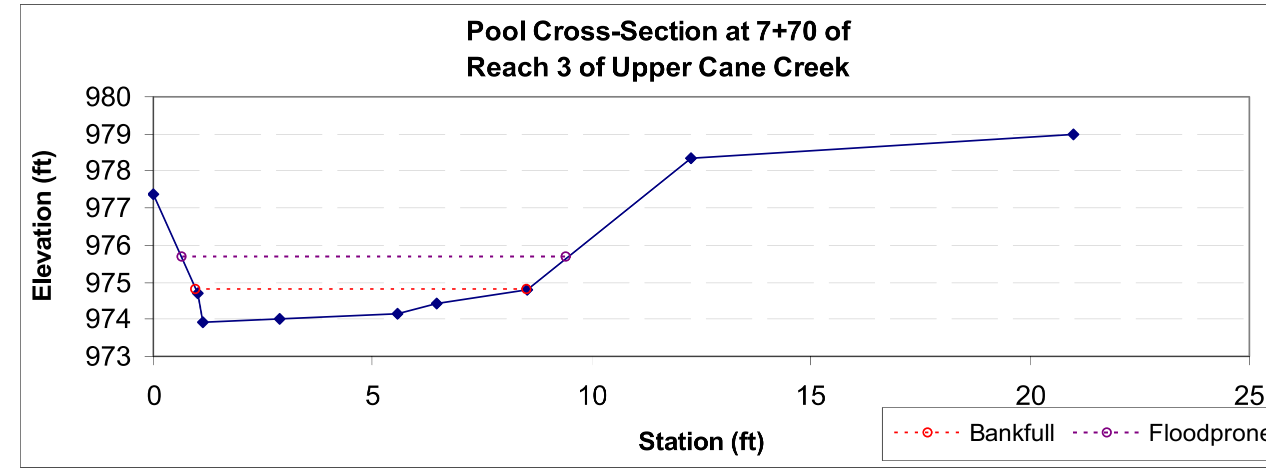


Right Fork of Upper Cane Creek
Profile Data

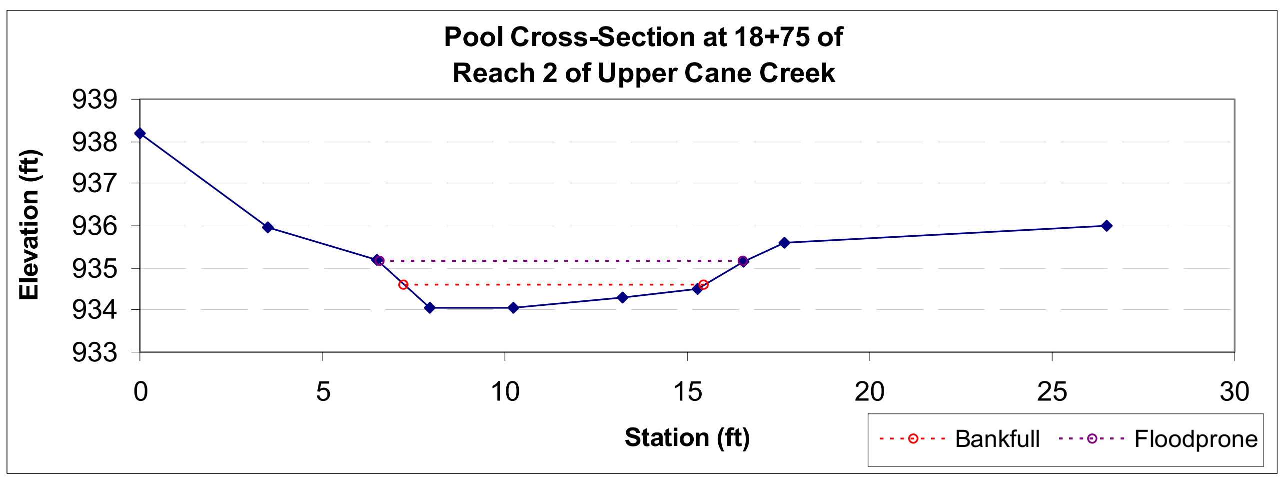
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	B	6.2	6.25	0.99	1.26	6.3	1.7	1.4	991.6	992.45



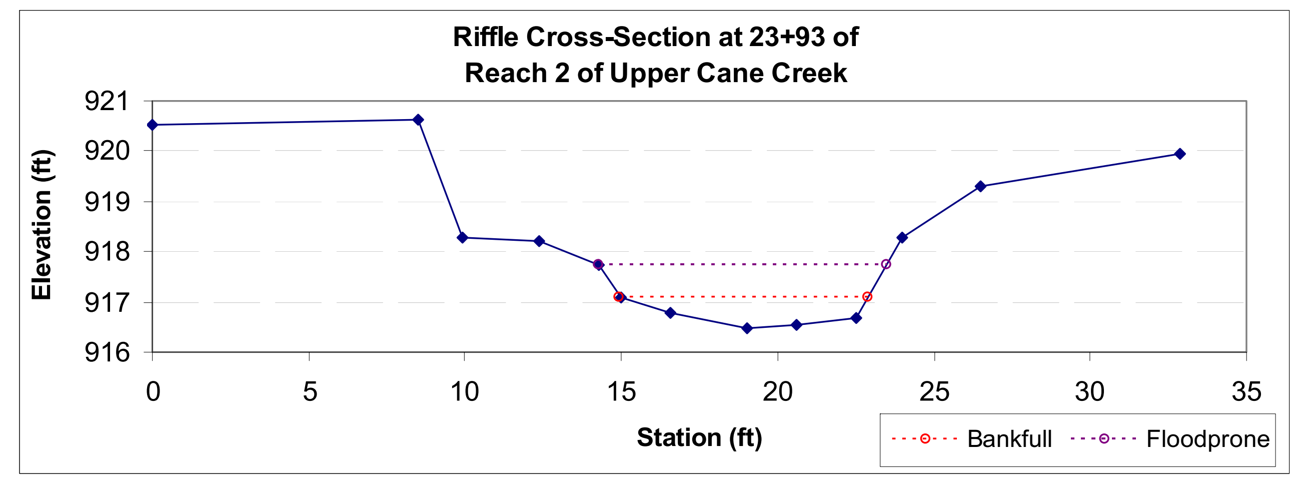
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	--	4.2	7.54	0.56	0.86	13.52	4	1.2	974.8	977.36



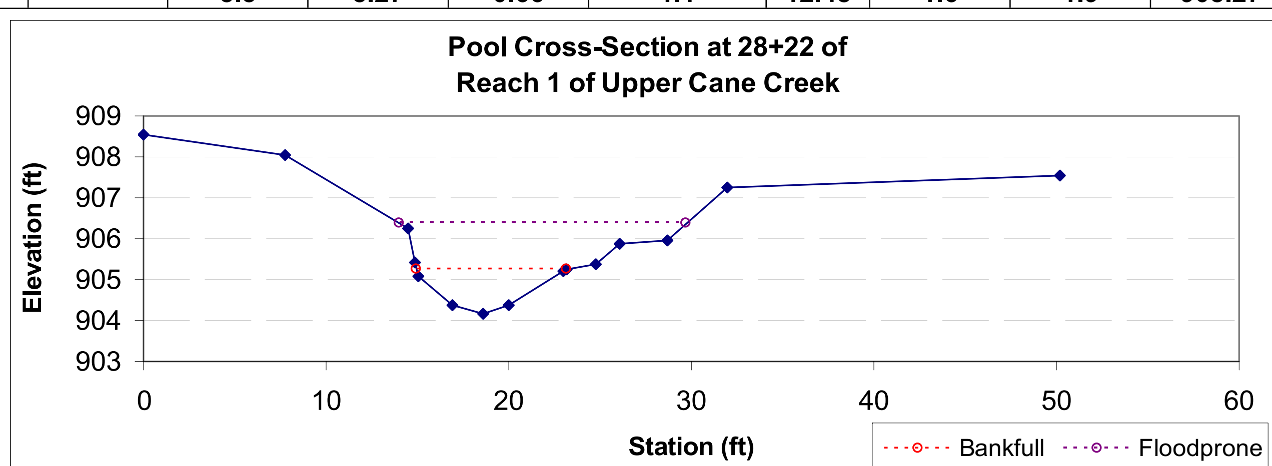
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	--	3.1	8.21	0.38	0.55	21.55	2	1.2	934.59	935.14



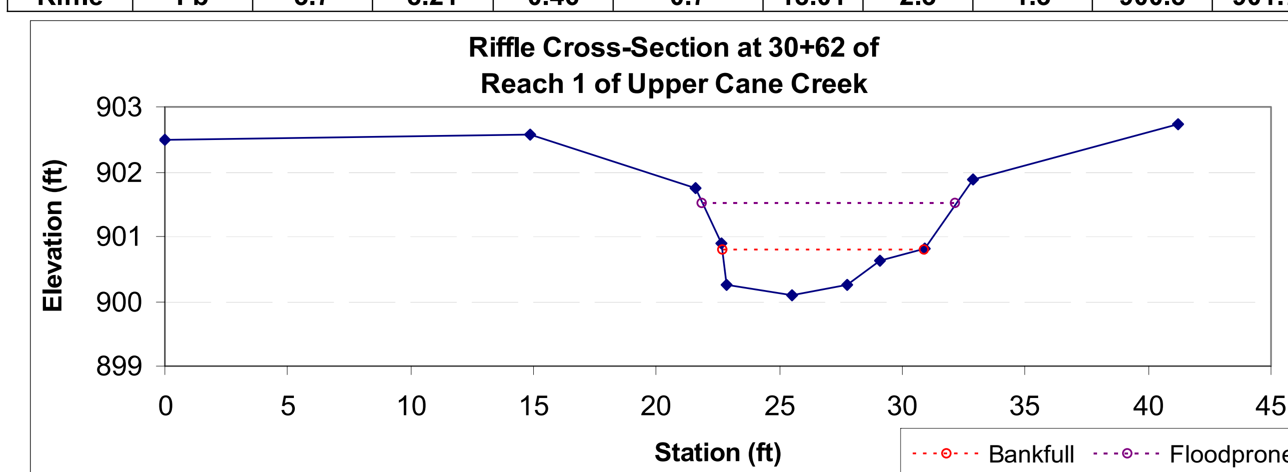
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	Fb	3.4	7.96	0.43	0.63	18.72	2	1.2	917.1	917.73



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	--	5.5	8.27	0.66	1.1	12.48	1.6	1.9	905.27	905.87



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	Fb	3.7	8.21	0.46	0.7	18.01	2.3	1.3	900.8	901.75

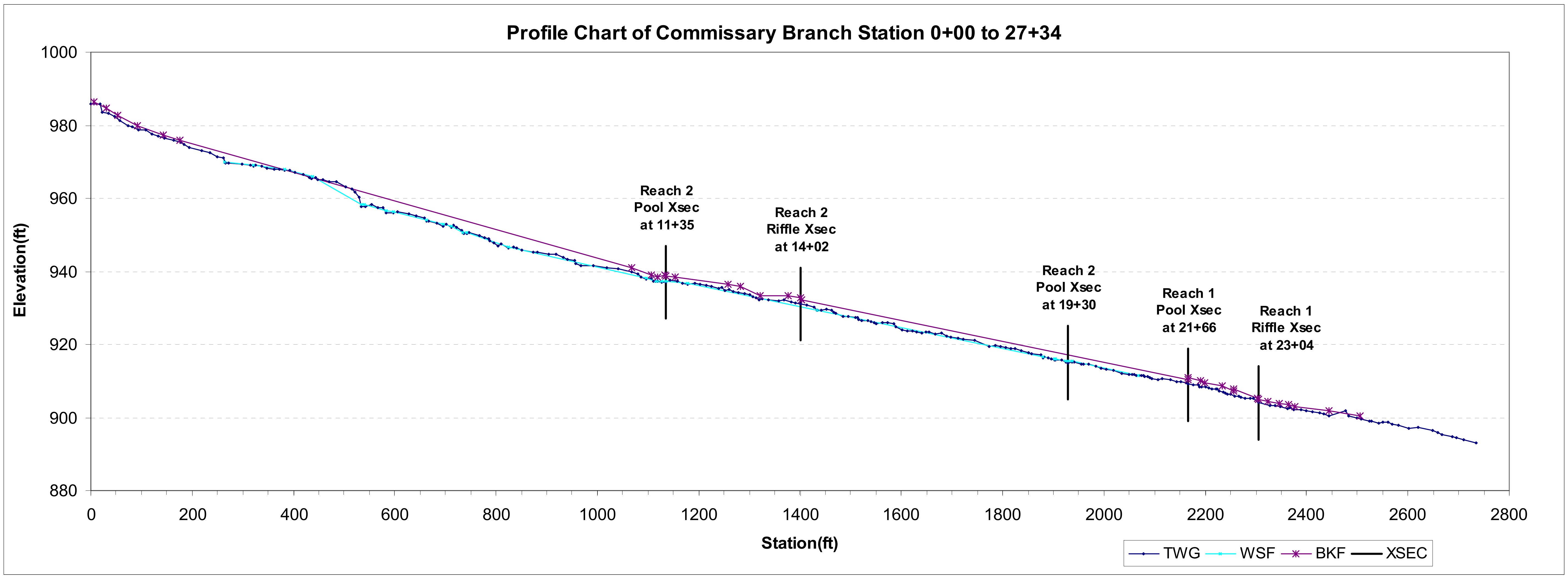


Right Fork of Upper Cane Creek
Cross-section Data

On-Site Existing Conditions Data For Commissary Branch and Tributaries

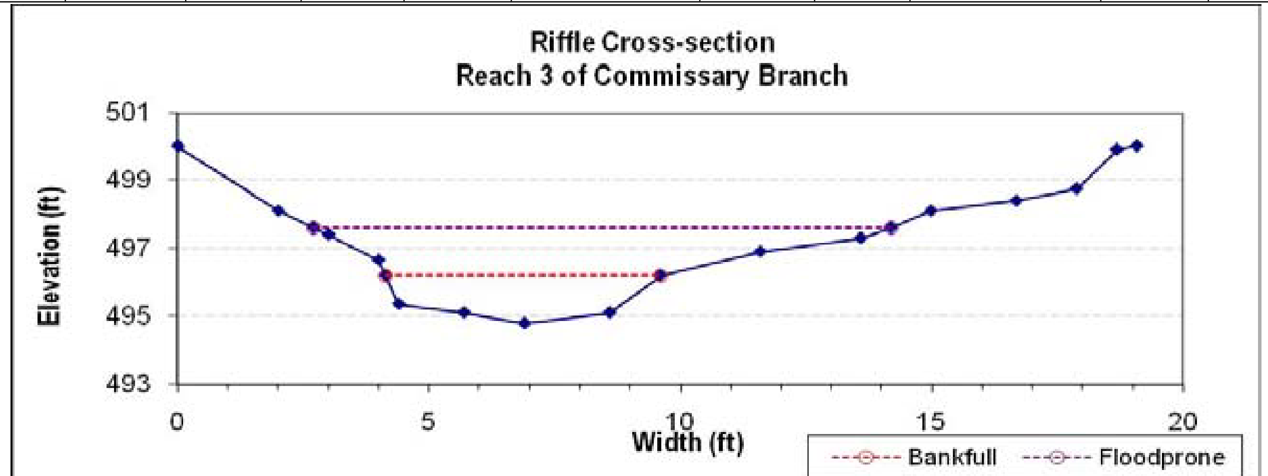
Parameter		Commissary Branch (Reaches 1 and 2) Minimum	Maximum	Average	Commissary Branch (Reach 3)	RUT2 of Commissary Branch
Rosgen Stream Type		----	----	B4	----	----
Drainage Area (sq mi)		----	----	0.318	0.095	0.031
Reach Length Surveyed (ft)		----	----	2733.97	----	----
Dimension	Bankfull Width (ft)	10.61	15.65	13.13	5.46	7.82
	Bankfull Mean Depth (ft)	0.63	0.76	0.69	0.9	1.0
	Width/Depth Ratio	14	24.9	19.4	5.9	7.4
	Bankfull Area (sq ft)	8.04	9.84	8.94	5.0	8.3
	Bankfull Max Depth (ft)	1.04	1.08	1.06	1.4	1.8
	Width of Floodprone Area (ft)	14.4	19.6	17	11.5	21.0
	Entrenchment Ratio	1.3	1.4	1.3	2.1	2.7
	Max Pool Depth (ft)	0.9	1.7	1.4	----	----
	Ratio of Max Pool Depth to Bankfull Depth	1.3	2.4	2.1	----	----
	Pool Width (ft)	9.02	10.05	9.38	----	----
	Ratio of Pool Width to Bankfull Width	0.7	0.8	0.7	----	----
	Pool to Pool Spacing (ft)	1.15	139.60	78.40	----	----
	Ratio of Pool to Pool Spacing to Bankfull Width	0.10	12.14	6.82	----	----
	Bank Height Ratio	1.8	2.6	2.2	1.0	1.0
Pattern	Meander Length (ft)	----	----	----	----	----
	Meander Length Ratio	----	----	----	----	----
	Radius of Curvature (ft)	----	----	----	----	----
	Radius of Curvature Ratio	----	----	----	----	----
	Meander Belt Width (ft)	----	----	----	----	----
	Meander Width Ratio	----	----	----	----	----
	Sinuosity	----	----	1.22	----	----
Profile	Valley Slope (ft/ft)	----	----	0.0394	----	----
	WS Slope (ft/ft)	----	----	0.0324	----	----
	Channel Slope (ft/ft)	----	----	0.034	----	----
	Pool Slope (ft/ft)	0.001	0.012	0.006	----	----
	Ratio of Pool Slope to WS Slope	0.016	0.376	0.196	----	----

B channels have low to moderate sinuosity and typically do have meander geometry.

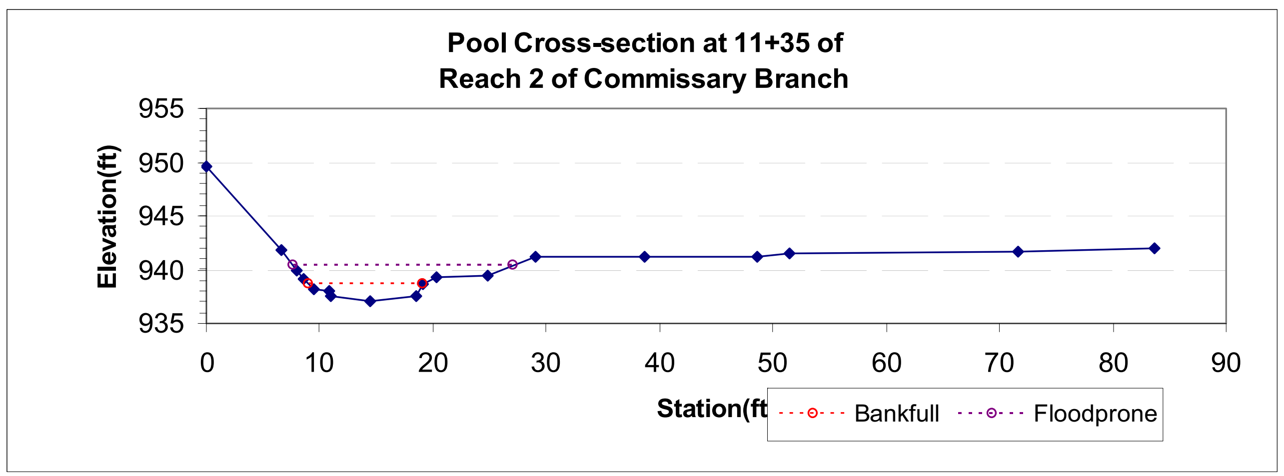


Commissary Branch
Profile and Cross-section Data

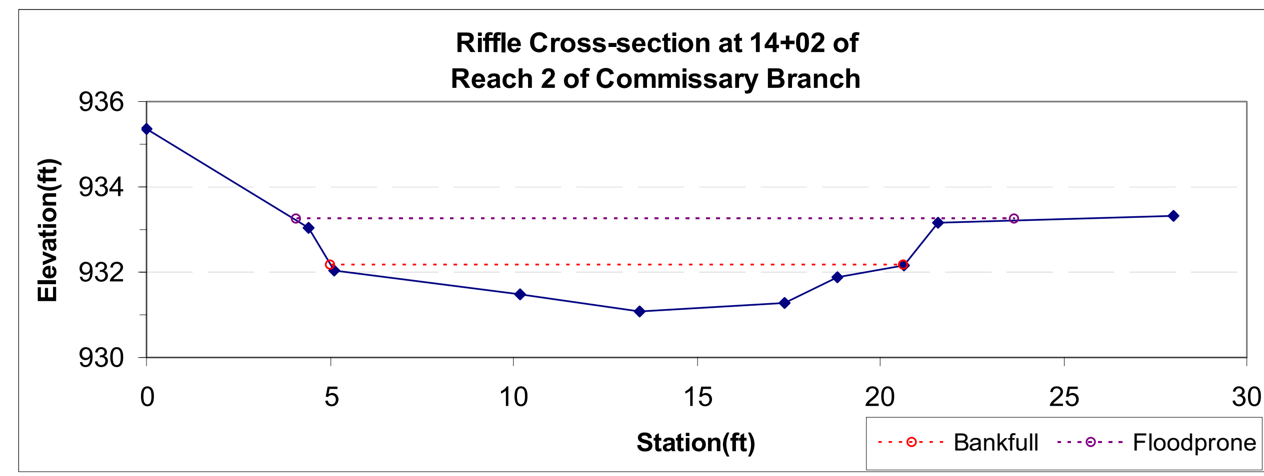
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	A	5.55	5.46	1.02	1.40	5.37	1.00	2.11	--	--



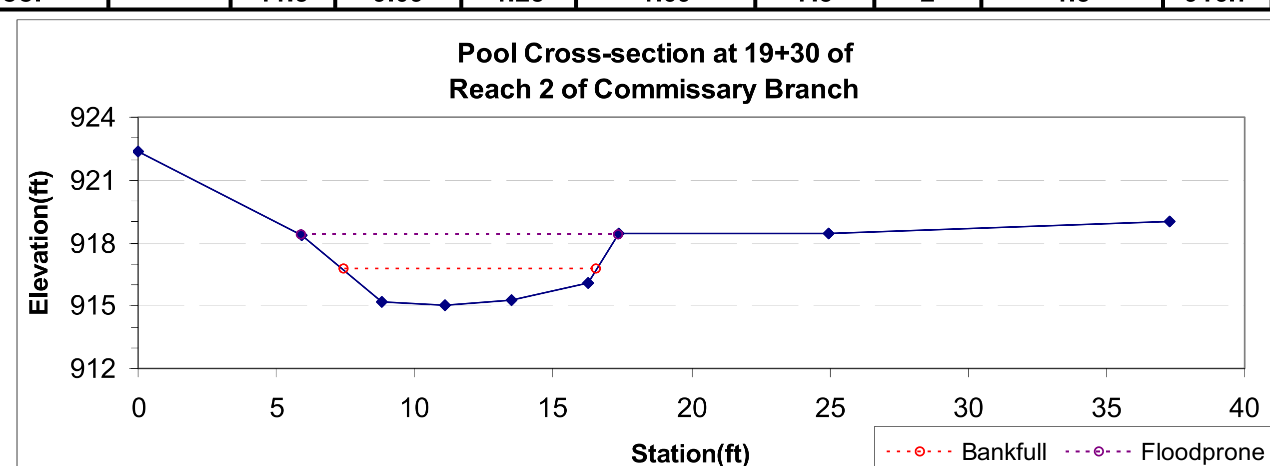
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	---	11.8	10.05	1.18	1.66	8.54	1.4	1.9	938.66	939.29



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	F4b	9.8	15.65	0.63	1.08	24.87	1.8	1.3	932.15	933.06

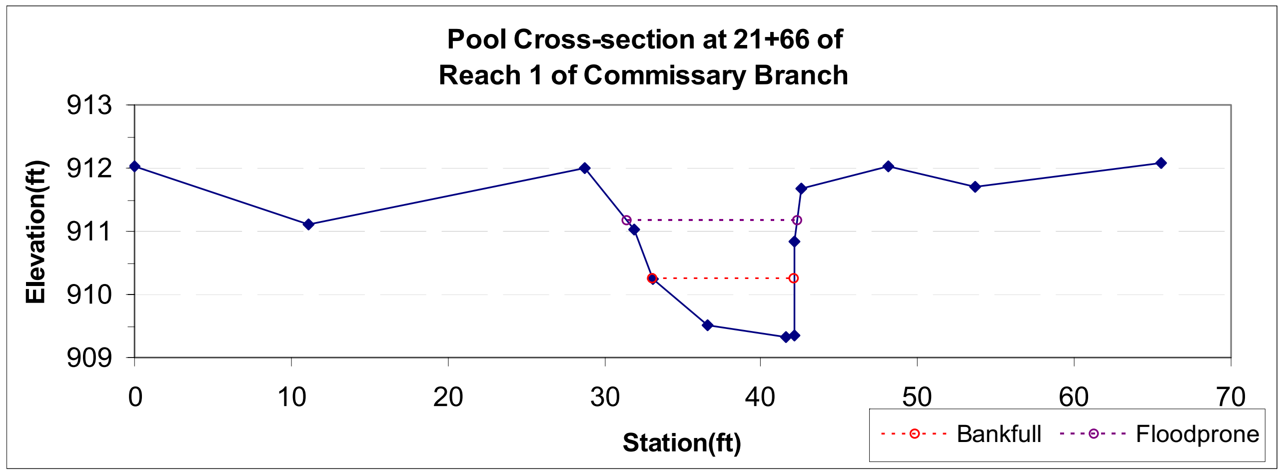


Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool	---	11.3	9.09	1.25	1.69	7.3	2	1.3	916.7	918.39

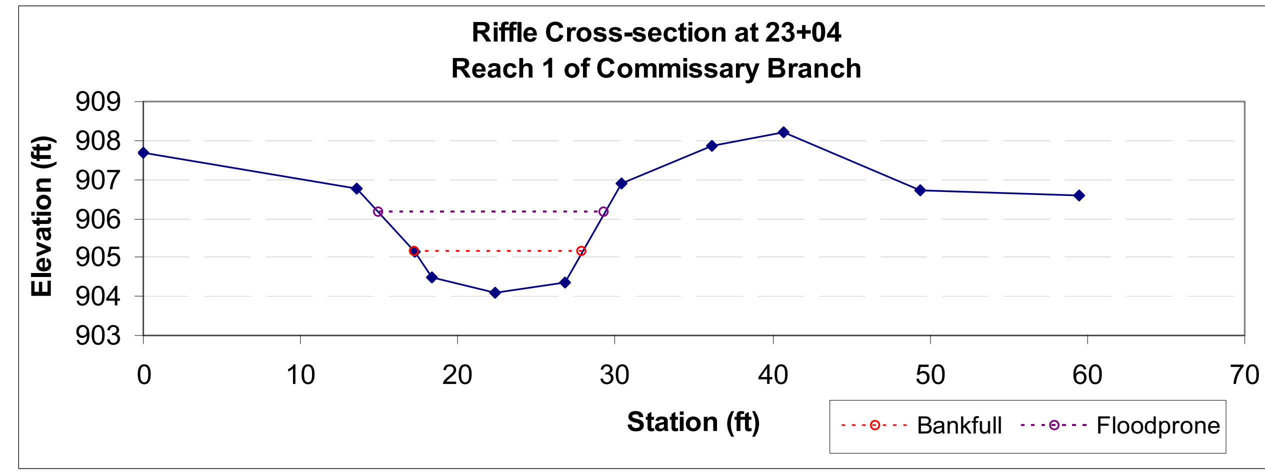


Commissary Branch
Profile and Cross-section Data

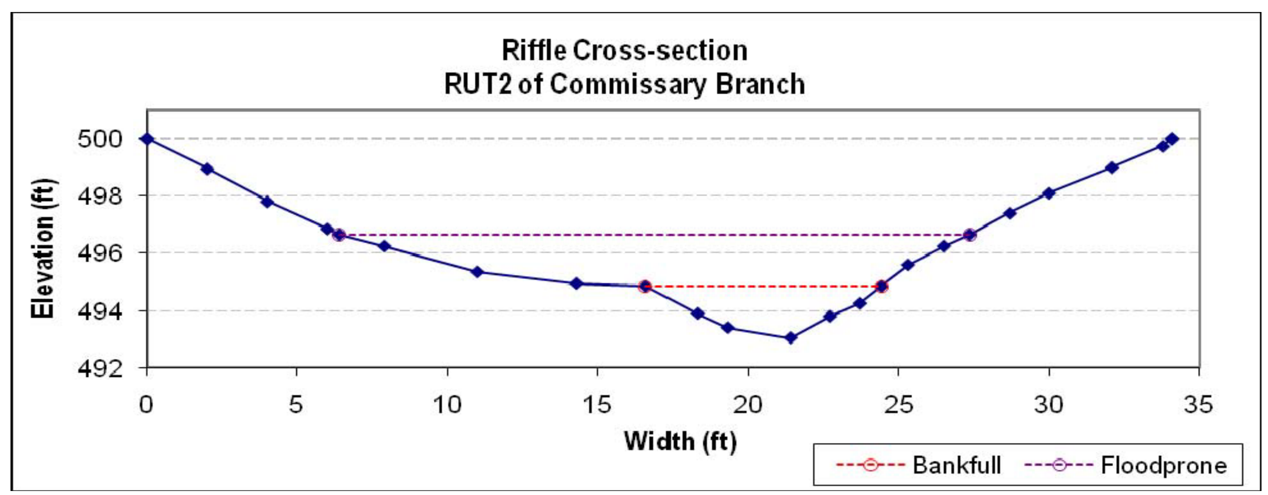
Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Pool		5.9	9.02	0.65	0.91	13.89	1.9	1.2	910.24	911.03



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	B	8	10.61	0.76	1.04	13.99	2.6	1.4	905.13	906.78



Feature	Stream Type	BKF Area	BKF Width	BKF Depth	Max BKF Depth	W/D	BH Ratio	ER	BKF Elev	TOB Elev
Riffle	A	8.22	7.82	1.05	1.80	7.44	1.00	2.68	--	--



Commissary Branch and Tributary
Cross-section Data

APPENDIX G

PHOTOGRAPHS

Right Fork of Upper Cane Creek

Reach 1 of Right Fork of Upper Cane Creek

Reach 2 of Right Fork of Upper Cane Creek

Reach 3 of Right Fork of Upper Cane Creek

Reach 4 of Right Fork of Upper Cane Creek

Tributaries of Right Fork of Upper Cane Creek

- RUT1
- LUT1




RUT1 of Right Fork of Upper Cane Creek




LUT1 of Right Fork of Upper Cane Creek

Commissary Branch

Reach 1 of Commissary Branch




Reach 2 of Commissary Branch

Reach 3 of Commissary Branch

Tributaries of Commissary Branch

- RUT1
- RUT2
- LUT1

RUT1 of Commissary Branch

RUT2 of Commissary Branch

LUT1 of Commissary Branch

APPENDIX H

BIOTIC ASSESSMENT DATA

Table F-1
Benthic Macroinvertebrate Metric

Site	Upper Cane Creek - Upstream	Upper Cane Creek - Do nstream	Upper Cane Creek Belo Project Area	Commissary Branch - Upstream	Commissary Branch - Do nstream
Summary Metrics					
Total Number of Individuals	673	839	792	879	1121
Total Number of Taxa	24	21	21	26	26
Total Number EPT Taxa	12	10	11	14	14
Modified Percent EPT	48	36	79	49	65
Percent Ephemeroptera	33	35	68	36	59
Percent Chironomidae + Oligochaeta	3	5	2	5	4
Percent Primary Clingers	10	15	37	25	23
Percent 2 Dominant Taxa	57	70	56	53	64
mHBI	3.7	4.1	3.5	3.7	3.7
Simpson's Diversity Index	0.785	0.703	0.800	0.801	0.774

Table F-2
Benthic Macroinvertebrate Individual Count Summary

ORDER	FAMILY	FUNCTIONAL FEEDING GROUP	Tolerance Value	Upper Cane Creek - Upstream	Upper Cane Creek - Do nstream	Upper Cane Creek - Belo Project Area	Commissary Branch - Upstream	Commissary Branch - Do nstream
Ephemeroptera	Baetidae	Collector-gatherers	4	112	175	290	40	404
	Ephemerellidae	Collector-gatherers	2	6	8	68	107	60
	Ephemeridae	Collector-gatherers	4	46	34		14	4
	Heptageniidae	Scrapers	3	36	60	150	43	131
	Leptophlibiidae	Collector-gatherers	4	21	9	24	49	28
	Siphlonuridae	Collector-gatherers	4		4	8	65	35
Plecoptera (Stone Flies)	Chloroperlidae	Predators	0	2	1	39		15
	Leuctridae	Shredders	0				12	
	Nemouridae	Shredders	2	95	2	17	21	11
	Peltoperlidae	Shredders	0	3			9	6
	Perlidae	Predators	3	1	5	5	20	6
	Perlodidae	Predators	2		5	14	23	22
Trichoptera (caddisflies)	Hydropsychidae	Collector-filterers	5	2		5	14	4
	Limnephilidae	Shredders	4	1			8	
	Philopotamidae	Collector-filterers	4					3
	Polycentropodidae	Predators	6				2	
	Rhyacophilidae	Predators	1			3		2
	Uenonidae	Scrapers	3	1				
Diptera (True Flies)	Ceratopogonidae	Predators	6			1	2	2
	Chironomidae	Collector-gatherers	6	23	36	15	45	41
	Dixidae	Collector-filterers	1	2	1		4	1
	Simuliidae	Collector-filterers	6					1
	Tipulidae	Shredders	4	19	15	15	21	14
Coleoptera (Beetles)	Dytiscidae	Predators	5			1		
	Elmidae	Scrapers	5	10	12	5	1	5
	Psephenidae	Scrapers	4	5	38	2	2	6
Odonata (Dragonflies)	Gomphidae	Predators	4	2	1		3	1
Megaloptera	Sialidae	Predators	4	1			2	
Lepidoptera	Pyralidae	Shredders	5	1				
Decapoda	Cambaridae	Collector-gatherers	6	6	1	4	1	3
Amphipoda	Gammaridae	Collector-gatherers	4	272	413	106	358	309
Isopoda	Asellidae	Collector-gatherers	8	4	16	19	11	6
Tubificida	Tubificidae	Collector-gatherers	10		2	1	2	1
Basommatophora	Planorbidae	Scrapers	6	2				
Veneroidea	Sphaeriidae	Collector-filterers	6		1			
Totals				673	839	792	879	1,121

Table F-3
Surface Water Chemistry Results

Site-ID	Upper Cane Creek - Upstream	Upper Cane Creek - Do nstream	Upper Cane Creek - Belo Project Area	Commissary Branch - Upstream	Commissary Branch - Do nstream
Field Measurements					
Temperature (C)	12.9	13.4	12.6	11.7	11.3
Dissolved Oxygen (mg/L)	8.80	9.10	9.60	10.20	9.40
Conductivity (µS/cm)	240	200	160	120	120
pH	7.70	7.80	7.60	7.40	7.10

Table F-4
Physical Habitat Assessment Summary

Site	Upper Cane Creek - Upstream	Upper Cane Creek - Do nstream	Upper Cane Creek - Belo Project Area	Commissary Branch - Upstream	Commissary Branch - Do nstream
Habitat					
Reach Length (meters)	100	100	100	100	100
Vegetation ( )	0	0	0	0	10
Snags ( )	20	5	20	15	5
Riffle ( )	75	85	70	85	75
Bedrock ( )	0	0	5	0	5
Sand ( )	5	10	5	0	5

Table F-5
Benthic HAV Summary

Watershed	Upper Cane Creek				Commissary Branch				
Stream Name	Right Fork of Upper Cane Creek		RUT1 of Right Fork of Upper Cane Creek	LUT1 of Right Fork of Upper Cane Creek	Commissary Branch		RUT1 of Commissary Branch	RUT2 of Commissary Branch	LUT1 of Commissary Branch
Gradient (high or lo)	High	High	High	High	High	High	High	High	High
Reach	1-2	3-4	N/A	N/A	1-2	3	N/A	N/A	N/A
1. Epifaunal Substrate/ Available Cover (0-20)	16	16	10	11	18	13	7	12	6
2. Embeddedness (0-20)	11	11	14	15	13	12	15	10	10
3. Velocity/Depth Regime (0-20)	15	14	1	1	13	11	1	1	1
4. Sediment Deposition (0-20)	15	11	10	10	8	11	15	10	10
5. Channel Flo Status (0-20)	14	14	1	1	9	8	1	15	1
6. Channel Alteration (0-20)	13	15	10	16	15	15	15	5	16
7. Frequency of Riffles (or bends) (0-20)	11	14	14	14	13	8	2	5	12
8. Left Bank Stability (0-10)	9	8	7	8	3	7	3	5	8
8. Right Bank Stability (0-10)	9	6	6	8	7	8	3	5	8
9. Left Vegetative Protection (0-10)	9	7	7	7	7	9	3	1	8
9. Right Vegetative Protection (0-10)	9	7	6	7	7	9	3	1	8
10. Left Riparian Vegetative one Width (0-10)	2	9	8	9	9	8	9	6	9
10. Right Riparian Vegetative one Width (0-10)	9	1	5	9	5	8	9	4	9
Habitat Assessment Value	142	133	99	116	127	127	86	80	106
Average	123				105				

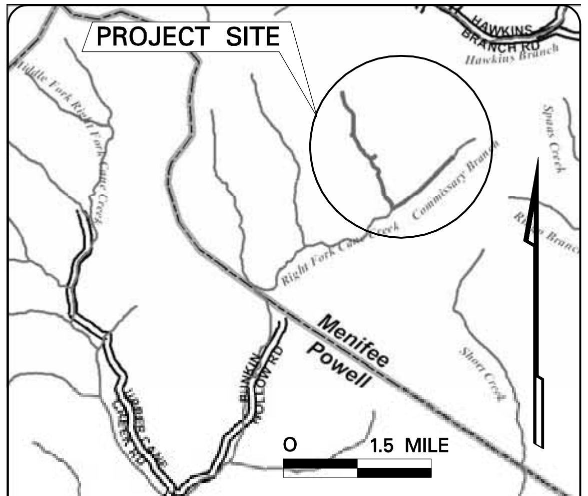
APPENDIX I

STREAM RESTORATION/ENHANCEMENT

AND ROAD RELOCATION

DESIGN PLAN SHEETS

STREAM RESTORATION & ENHANCEMENT AND ROAD RELOCATION
MENIFEE COUNTY
UPPER CANE CREEK



VICINITY MAP

KENTUCKY DEPARTMENT OF FISH & WILDLIFE RESOURCES
#1 SPORTSMAN'S LANE
FRANKFORT, KY 40601
Account # 660–C1KN–5402–00

COMMONWEALTH OF KENTUCKY
GOVERNOR STEVE BESHEAR

FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING AND CONTRACT ADMINISTRATION

INDEX OF DRAWINGS

STREAM RESTORATION & ENHANCEMENT

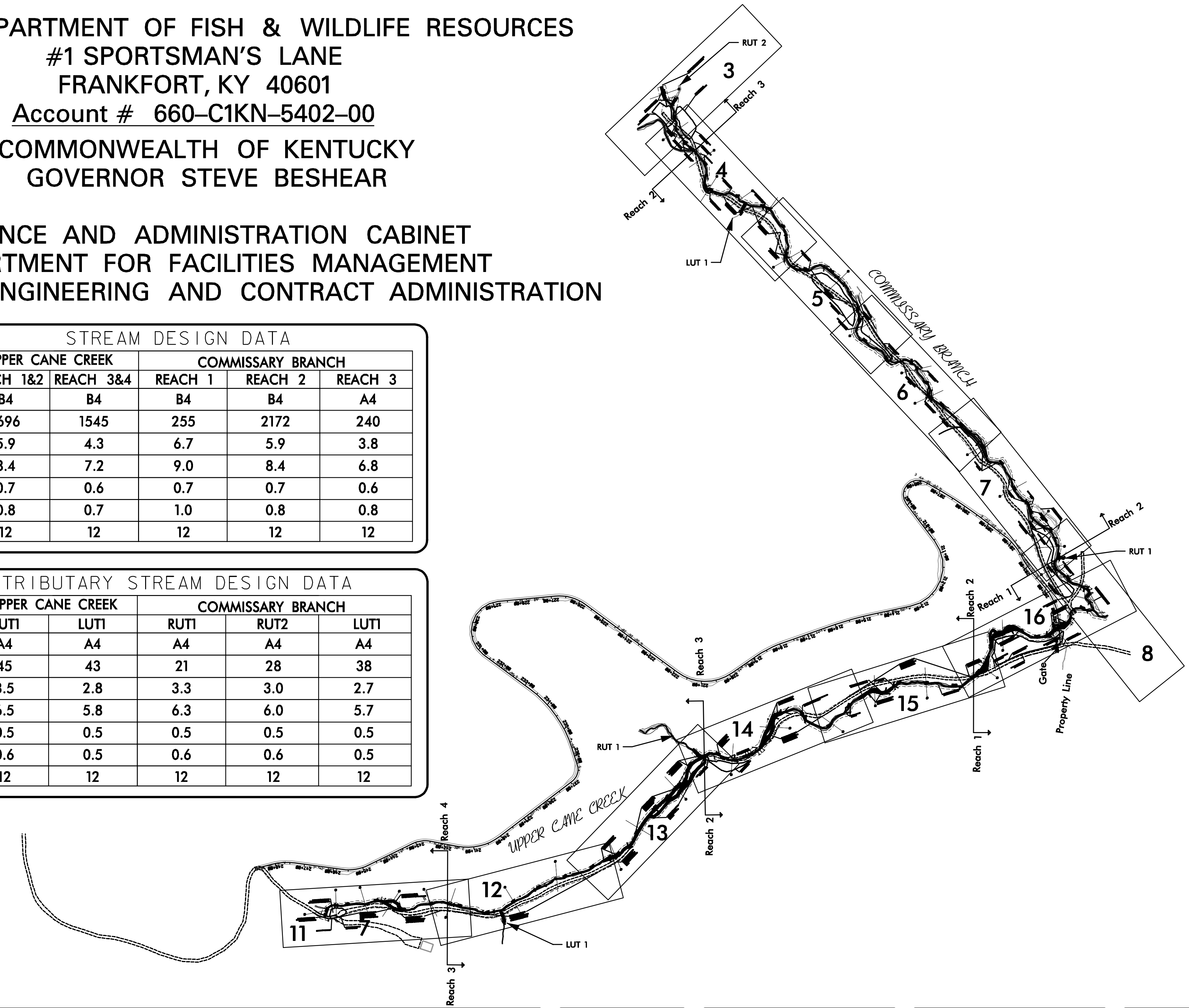
ROAD RELOCATION

STREAM DESIGN DATA

	UPPER CANE CREEK		COMMISSARY BRANCH		
	REACH 1&2	REACH 3&4	REACH 1	REACH 2	REACH 3
DESIGN STREAM TYPE	B4	B4	B4	B4	A4
DESIGN REACH LENGTH (LF)	1696	1545	255	2172	240
BANKFULL XSEC AREA (SF)	5.9	4.3	6.7	5.9	3.8
BANKFULL WIDTH (FT)	8.4	7.2	9.0	8.4	6.8
BANKFULL MEAN DEPTH (FT)	0.7	0.6	0.7	0.7	0.6
BANKFULL MAX DEPTH (FT)	0.8	0.7	1.0	0.8	0.8
W/D RATIO	12	12	12	12	12

TRIBUTARY STREAM DESIGN DATA

	UPPER CANE CREEK		COMMISSARY BRANCH		
	RUT1	LUT1	RUT1	RUT2	LUT1
DESIGN STREAM TYPE	A4	A4	A4	A4	A4
DESIGN REACH LENGTH (LF)	45	43	21	28	38
BANKFULL XSEC AREA (SF)	3.5	2.8	3.3	3.0	2.7
BANKFULL WIDTH (FT)	6.5	5.8	6.3	6.0	5.7
BANKFULL MEAN DEPTH (FT)	0.5	0.5	0.5	0.5	0.5
BANKFULL MAX DEPTH (FT)	0.6	0.5	0.6	0.6	0.5
W/D RATIO	12	12	12	12	12



NO.	DATE	BY	REVISION

PRELIMINARY PLANS
DO NOT USE FOR CONSTRUCTION
01/19/09

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker
Michael Baker Jr., Inc.
5088 West Washington Street
Charleston, West Virginia 25313
Phone 304-769-0821
Fax 304-769-0822

LETTING DATE:

P. Fogarty
PROJECT ENGINEER
C. Mower / A. Rogers
PROJECT DESIGNER

PROJECT ENGINEER

P.E.

SIGNATURE:

SHEET 1 OF 19

STREAM RESTORATION & ENHANCEMENT AND ROAD RELOCATION MATERIAL SUMMARY

STREAM RESTORATION & ENHANCEMENT MATERIAL SUMMARY

ITEM CODE	DESCRIPTION	QUANTITY	UNITS
C	MOBILIZATION	1	LS
D	SILT FENCE	2,000	FT
F	MULCH	250	BALES
F	TEMPORARY SEED	1,100	LBS
G	PERMANENT SEED	150	LBS
F	SPREADING OF SEED[1]	3	ACRES
H	EXCAVATION, FILL AND GRADING	7,500	CU YARDS
H	ROUGHING OF SOIL[2]	2	ACRES
H	CLEARING	2	ACRES
H	GRUBBING	2	ACRES
I	BOULDERS	300	TONS
I	CLASS A/B STONE	550	TONS
K	FILTER FABRIC, TYPE II	1,100	SY
J	ROOT WADS	50	ROOT WADS
J	LOGS	115	LOGS
L	EROSION MAT	7,000	SY
N	LIVE STAKES	9,350	STAKES
S	BARE-ROOT PLANTING	3,750	STEMS

[1] Includes stream banks, road areas, & staging areas

[2] Includes road areas & staging areas

ROAD RELOCATION MATERIAL SUMMARY

ITEM CODE	DESCRIPTION	QUANTITY	UNITS
1	DGA BASE	1645	TN
2200	ROADWAY EXCAVATION	16058	CY
2483	CHANNEL LINING CLASS II	633	TN
2545	CLEARING AND GRUBBING	1	LS
2568	MOBILIZATION	1	LS
2598	FABRIC-GEOTEXTILE TYPE III	7296	SY
2679	POROUS UNDERDRAIN	201	LF
5950	EROSION CONTROL BLANKET	1445	SY
5953	TEMP SEEDING AND PROTECTION	6051	SY
5985	SEEDING AND PROTECTION	12101	SY
8019	CYCLOPEAN STONE RIPRAP	35	TN

STRUCTURE QUANTITIES

STRUCTURE	QUANTITY
LOG CROSS VANES	5
ROCK CROSS VANES	4
CONSTRUCTED RIFFLE	10
ROCK STEP POOL	35
LOG STEP POOL	19
LOG J-HOOK VANE	23
ROCK J-HOOK VANE	5
ROCK TOE PROTECTION	4
FORD ROAD CROSSING	4
ROOTWADS	14

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

CONSTRUCTION QUANTITIES

AS BUILT DATE: TBD
DRAWN BY: RT, CM, CF
CHECKED BY: FOGARTY
A&E FILE NO.: 110858
DATE: JAN. 19 2009

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

Baker
MICHAEL BAKER JR., INC.
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DRAWING NO. 1A

REVIEWED DIV. OF ENGR.
FOR INTENT ONLY
ACCOUNT NO. 660-CIKN-5402-00

SIGNATURE P.E.

AGENCY AUTHORIZED AGENT ______ APPROVED FOR PROGRAM CONCEPT ONLY DATE ______

DIVISION OF ENGINEERING ______ APPROVED FOR PROGRAM CONCEPT ONLY DATE ______

STREAM CONVENTIONAL SYMBOLS

- LOG STEP
- ROOT WAD
- LOG CROSS VANE
- GRADE CONTROL ROCK J–HOOK
- GRADE CONTROL LOG J–HOOK
- TEMPORARY STREAM CROSSING
- PERMANENT STREAM CROSSING
- ROCK CROSS VANE
- ROCK TOE PROTECTION
- ROCK STEP POOL
- BOULDER CLUSTER
- SILT FENCE
- SAFETY FENCE
- CONSERVATION EASEMENT
- TRANSPLANTED VEGETATION
- TREE REMOVAL
- TREE PROTECTION
- TEMPORARY SILT CHECK
- CONSTRUCTED RIFFLE
- TRANSPLANTS
- FILL EXISTING CHANNEL
- TEMPORARY STOCKPILE OR STAGING AREA

NOTE: NOT ALL SYMBOLS MAY BE USED.

GENERAL NOTES

Grading activities will be performed in the dry as much as possible. For instances in which the Contractor must work within the stream, a l equipment shall be removed from the channel at the end of each working day. The Contractor shall enter and exit the stream channel at locations where disturbance will be minimized. Silt checks shall be used in appropriated locations. The Contractor shall not disturb more stream bank area than can be stabilized in one working day. Erosion control matting and temporary seeding shall be placed on all disturbed banks, including temporary stockpile areas.

Excavated material will be temporarily stockpiled in designated areas. Silt fence shall be used to prevent sediment migration from the stockpiles toward the open channels on site. Any stockpiled soil which is not used within 15 working days or 30 calendar days, whichever is sooner, shall be covered with mulch and temporary seeding. Temporary stockpile areas, staging areas, and construction access' shall be regraded and seeded properly upon construction completion. Clearing limits are to be contained within valley and all valley slopes are to be protected.

ROCK SIZES

CLASS	ACCEPTANCE CRITERIA FOR RIP RAP AND STONE		
	MINIMUM	AVERAGE	MAXIMUM
WASHED 57 STONE	*0.25"*	*0.5"*	*1.5"*
A	*2"*	*4"*	*6"*
B	*5"*	*8"*	*12"*
I	*5"*	*10"*	*17"*
II	*9"*	*14"*	*23"*
*BOULDER 48"x36"x24"	*24"*	*36"*	*48"*

*Boulder sizes vary per design and channel dimensions

VEGETATION SELECTION

BARE-ROOT AND LIVE STAKE SPECIES

Common Name	Scientific Name	Percent Planted by Species	Planting Density
Streambanks (Live Stakes)			
Silky dogwood	*Cornus obliqua*	40%	65 to 100 stems per 1,000 SF
Silky willow	*Salix sericea*	40%	65 to 100 stems per 1,000 SF
Elderberry	*Sambucus canadensis*	20%	33 to 50 stems per 1,000 SF
Stream Riparian Buffer (Bare-root Trees)			
River birch	*Betula nigra*	30%	70 stems per acre
Tulip poplar	*Liriodendron tulipifera*	15%	140 stems per acre
Sycamore	*Platanus occidentalis*	20%	85 stems per acre
Northern red oak	*Quercus rubra*	20%	85 stems per acre
White oak	*Quercus alba*	15%	70 stems per acre
Alternate Species			
Swamp chestnut oak	*Quercus inichuaxii*		
Silky Cornel	*Cornus amomum*		
Black Willow	*Salix nigra*		
Ninebark	*Physocarpus opulifolius*		
Silver maple	*Acer saccharinum*		

PERMANENT SEED MIXTURE

Common Name	Scientific Name	Percent of Mixture	Seeding Density (lbs/acre)	Wetness Tolerance
Floodplain and Buffer Areas				
Virginia wildrye	*Elymus virginicus*	25%	2	FAC
Switchgrass	*Panicum virgatum*	25%	3	FAC+
Fox sedge	*Carex vulpinoidea*	25%	3	OBL
Redtop	*Agrostis alba*	25%	2	FAC
Restored Streambanks				
Virginia wildrye	*Elymus virginicus*	30%	12	FAC
Switchgrass	*Panicum virgatum*	30%	3	FAC+
Soft rush	*Juncus effusus*	20%	2	FACW+
Deertongue	*Dichathelium Clandestinum*	20%	12	FACW
Alternate Species				
Common Smartweed	*Polygonum hydropiper*			
Rice Cutgrass	*Leesia oryzoides*			
Wood Reed-Grass	*Cinna arundinacea*			

TEMPORARY SEEDING

The following table lists thetemporary seed mix for the project site. All disturbed areas will be stabilized using mulch and temporary seed.

Common Name	Rate	Dates
WINTER WHEAT	130 LBS/ACRE	NOVEMBER TO APRIL
WINTER OR PERENNIAL RYE	130 LBS/ACRE	NOVEMBER TO APRIL
BROWN TOP MILLET	40 LBS/ACRE	APRIL TO AUGUST

KENTUCKY FISH AND WILDLIFE
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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

AS BUILT DATE: TBD
DRAWN BY: RT, CM, CF
CHECKED BY: FOGARTY
A&E FILE NO.: 110858
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DETAIL SHEET

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
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DIVISION OF ENGINEERING
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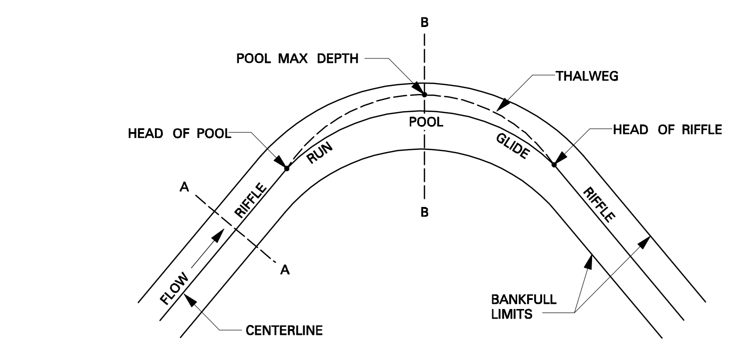
TYPICAL PLAN VIEW AND PROFILE

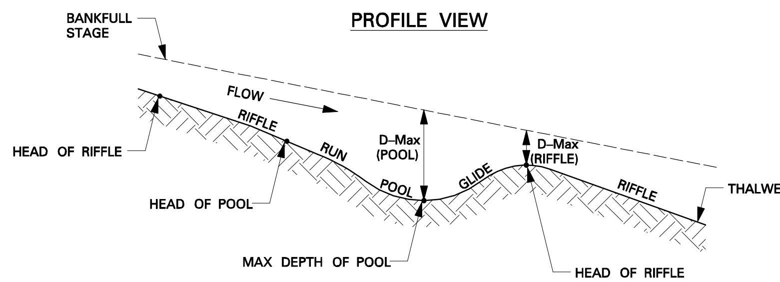
PLAN VIEW



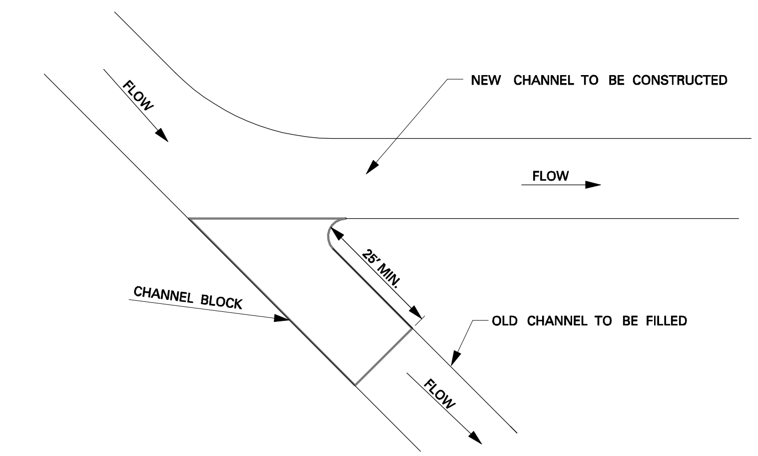
NOTES:

1. THE POINTS SHOWN, e.g. HEAD OF RIFFLE, HEAD OF POOL AND MAX DEPTH OF POOL ARE THE CONTROL POINTS USED TO CUT THE PROFILE; HOWEVER, THE CONTRACTOR SHOULD CREATE SMOOTH TRANSITIONS BETWEEN CONTROL POINTS AS SHOWN ABOVE.
2. USE THE FACET SLOPES IN THE TABLE AS A GUIDE TO ENSURE THAT THE FEATURES ARE APPROPRIATELY GRADED.
3. THE HEAD OF RIFFLE ELEVATION SHOULD NOT EXCEED THE HEAD OF POOL ELEVATION.
4. THE CHANGE IN WIDTH BETWEEN THE RIFFLES AND POOLS SHOULD OCCUR GRADUALLY OVER THE ENTIRE LENGTH OF THE BEND.

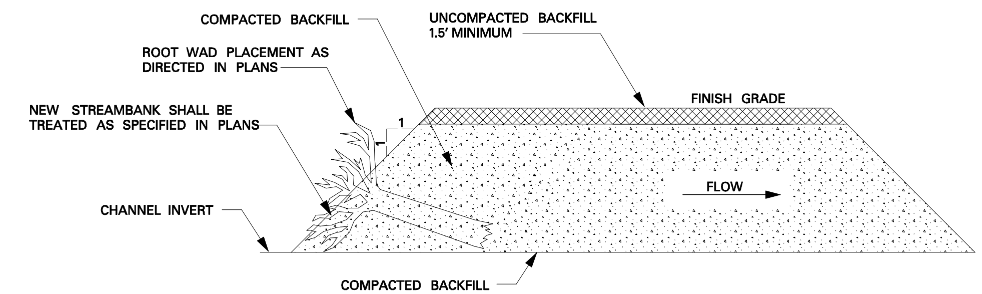
PROFILE VIEW



CHANNEL BLOCK

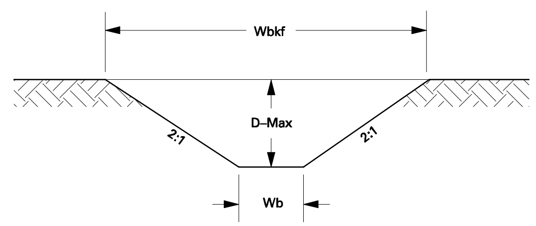


PLAN VIEW

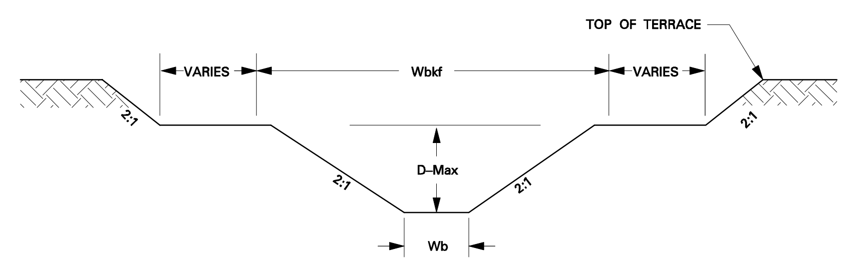


PROFILE VIEW

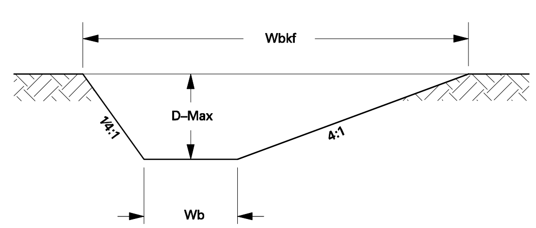
TYPICAL RIFFLE, POOL, AND BANKFULL BENCH CROSS SECTIONS



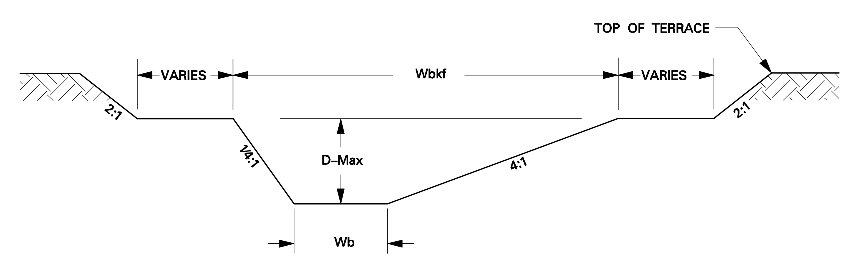
RIFFLE A–A



RIFFLE WITH BANKFULL BENCH



POOL B–B



POOL WITH BANKFULL BENCH

UPPER CANE CREEK				COMMISSARY BRANCH						
REACH 1&2		REACH 3&4		REACH 1		REACH 2		REACH 3		
RIFFLE	POOL	RIFFLE	POOL	RIFFLE	POOL	RIFFLE	POOL	RIFFLE	POOL	
8.4 ft	12.6 ft	7.2 ft	10.8 ft	9.0 ft	13.4 ft	8.4 ft	12.6 ft	6.8 ft	10.1 ft	WIDTH OF BANKFULL (Wbkf)
0.8 ft	1.4 ft	0.7 ft	1.2 ft	0.7 ft	1.5 ft	0.7 ft	1.4 ft	0.6 ft	1.1 ft	MINIMUM DEPTH (D)
0.8 ft	2.5 ft	0.7 ft	2.1 ft	1.0 ft	2.6 ft	0.8 ft	2.5 ft	0.8 ft	2.0 ft	MAXIMUM DEPTH (D–Max)
12	6.6	12	6.6	12	6.6	12	6.6	12	6.6	WIDTH TO DEPTH RATIO (Wbkf/D)
5.9 sq ft	8.0 ft/ft	4.3 sq ft	6.5 ft/ft	6.7 sq ft	13.4 ft/ft	5.9 sq ft	11.8 ft/ft	3.8 sq ft	7.6 ft/ft	BANKFULL AREA (Abkf)
3.2 ft	1.5	3.0 ft	1.5	5.2 ft	2.4 ft	4.9 ft	2.0 ft	3.9 ft	1.6 ft	BOTTOM WIDTH (Wb)

NOTES:

1. DURING CONSTRUCTION CORNERS OF DESIGN CHANNEL WILL BE ROUNDED AND A THALWEG WILL BE SHAPED PER DIRECTION OF ENGINEER.
2. POOLS SHOWN ABOVE ARE LEFT POOLS ONLY.
3. IF POSSIBLE, BUILD BANKFULL BENCH CROSS SECTIONS THROUGHOUT PROJECT.

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

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REVISIONS	DATE
1	
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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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DETAIL SHEET

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

DRAWING NO. 2

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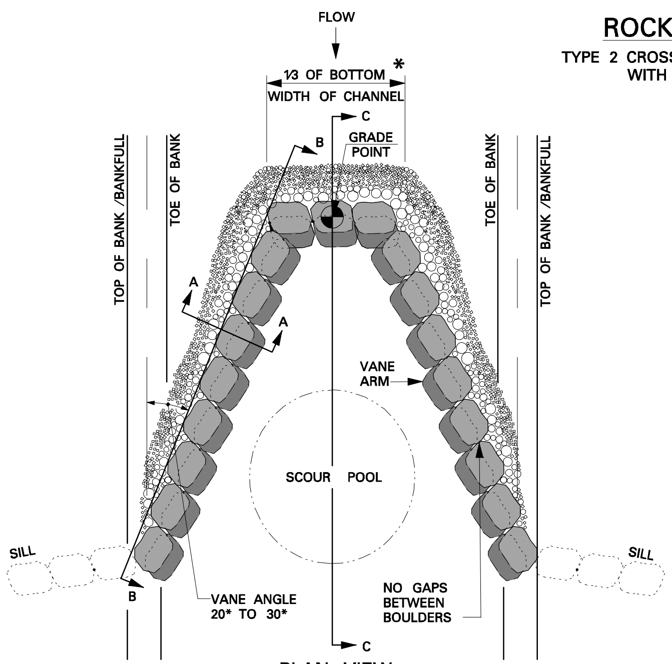
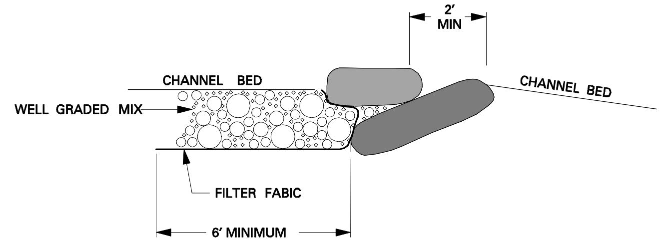
ROCK CROSS VANE TYPE 2

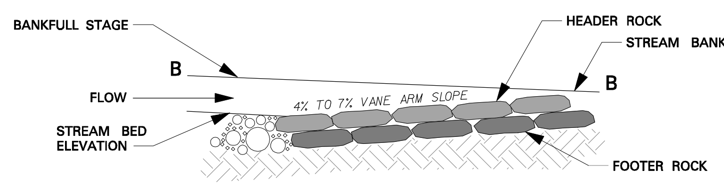
TYPE 2 CROSS VANE FOR GRAVEL/SAND BED STREAMS
WITH DRAINAGE ARES LESS THAN 12mi



PLAN VIEW



SECTION A – A

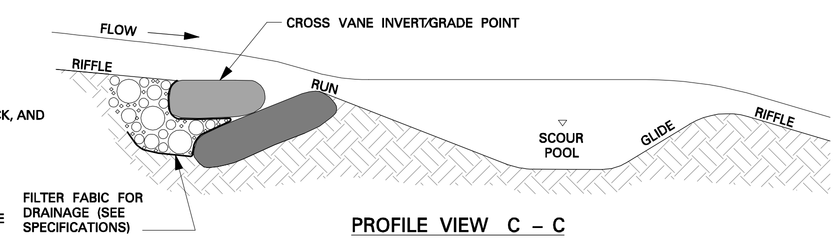


PROFILE VIEW B – B

VANE ARM

NOTES FOR ALL VANE STRUCTURES:

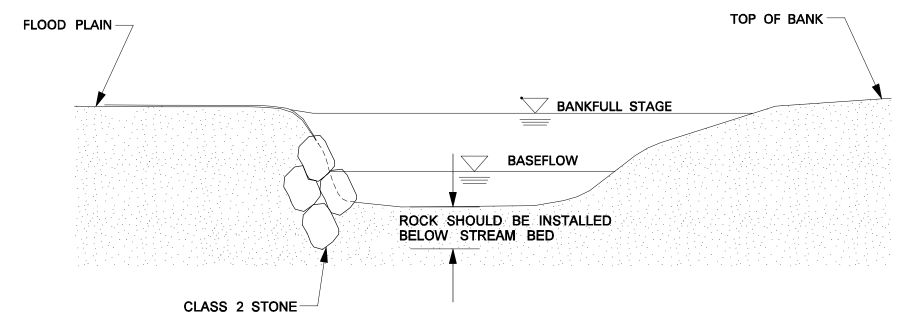
1. BOULDERS MUST BE AT LEAST 3' x 3' x 2'.
2. INSTALL FILTER FABRIC FOR DRAINAGE BEGINNING AT THE MIDDLE OF THE HEADER ROCKS AND EXTEND DOWNWARD TO THE DEPTH OF THE BOTTOM FOOTER ROCK, AND THEN UPSTREAM TO A MINIMUM OF SIX FEET.
3. DIG A TRENCH BELOW THE BED FOR FOOTER ROCKS AND PLACE FILL ON UPSTREAM SIDE OF VANE ARM, BETWEEN THE ARM AND STREAMBANK.
4. CONSTRUCT FOLLOWING ANGLE AND SLOPE SPECIFICATIONS.
5. USE CLASS 1 STONE TO FILL GAPS ON UPSTREAM SIDE OF BOULDERS, AND CLASS A STONE TO FILL GAPS ON UPSTREAM SIDE OF CLASS 1 STONE.
6. AFTER ALL STONE HAS BEEN PLACED, FILL IN THE UPSTREAM SIDE OF THE STRUCTURE WITH ON-SITE ALLUVIUM TO THE ELEVATION OF ONE HALF THE HEADER ROCK.



PROFILE VIEW C – C

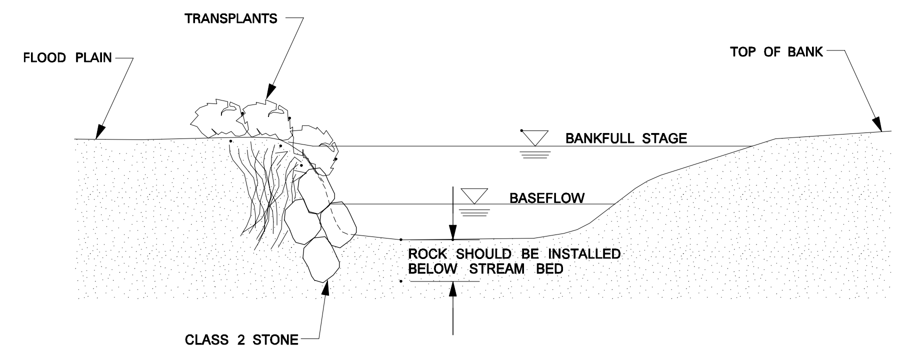
ROCK TOE PROTECTION

CROSS SECTION VIEW
NTS



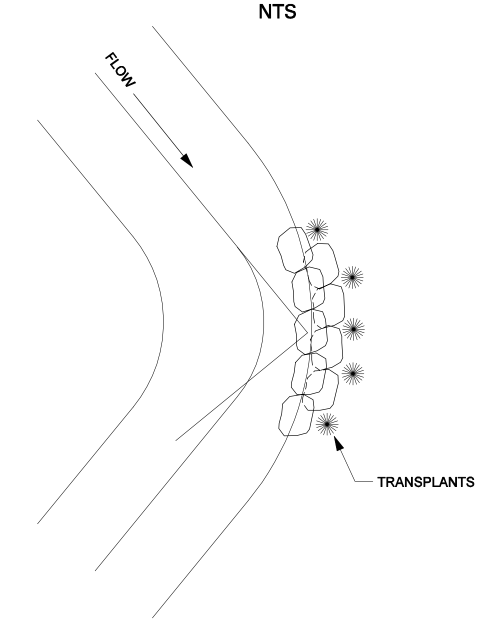
ROCK TOE PROTECTION WITH TRANSPLANTS

CROSS SECTION VIEW
NTS



ROCK TOE PROTECTION

PLAN VIEW
NTS



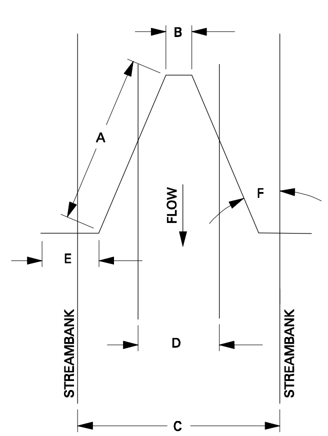
NOTES:

TRENCHING METHOD:
IF THE CLASS 2 CANNOT BE DRIVEN INTO THE BANK OR THE BANK NEEDS TO BE RECONSTRUCTED, THE TRENCHING METHOD SHOULD BE USED. THIS METHOD REQUIRES THAT A TRENCH BE EXCAVATED FOR THE CLASS 2. ONE-THIRD OF THE CLASS 2 SHOULD REMAIN BELOW NORMAL BASE FLOW CONDITIONS.

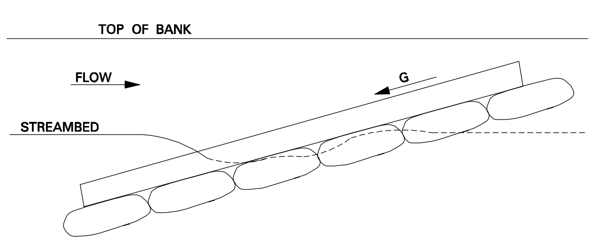
NOTES:

DRIVEN METHOD:
CLASS 2 SHOULD BE LAIN IN THE STREAMBED AND THEN DRIVEN INTO THE BANK WITH A HORIZONTAL AND DOWNWARD FORCE.

LOG CROSS VANE TYPICAL



PLAN VIEW



PROFILE VIEW

		COMMISSARY BRANCH			UPPER CANE CREEK	
		REACH 1	REACH 2	REACH 3	REACH1&2	REACH3&4
A	Vane Arm Length	10.9 ft	10.1 ft	8.2 ft	9.9 ft	8.5 ft
B	Invert Length	1.6 ft	1.5 ft	1.2 ft	1.6 ft	1.4 ft
C	Bankfull Width	9.0 ft	8.4 ft	6.8 ft	8.4 ft	7.2 ft
D	Bottom Width	5.2 ft	4.9 ft	3.9 ft	4.9 ft	4.1 ft
E	Sill Length	6.0 ft	6.0 ft	6.0 ft	8.0 ft	8.0 ft
F	Vane Arm Angle	20.0°	20.0°	20.0°	20.0°	20.0°
G	Vane Arm Slope	6.2%	5.3%	6.5%	5.4%	5.5%
H	Structure Length	10.2 ft	9.5 ft	7.7 ft	9.3 ft	8.0 ft

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MENIFEE COUNTY, KENTUCKY

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

DETAIL SHEET

AS BUILT DATE: TBD
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A&E FILE NO.: 110858
DATE: JAN. 19 2009

COMMONWEALTH OF KENTUCKY
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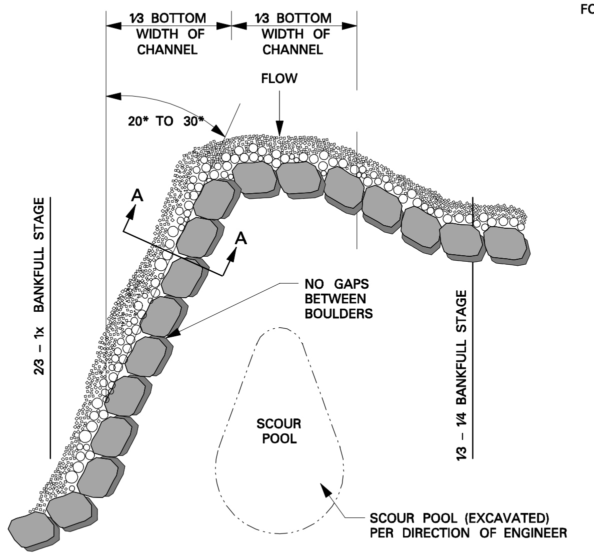
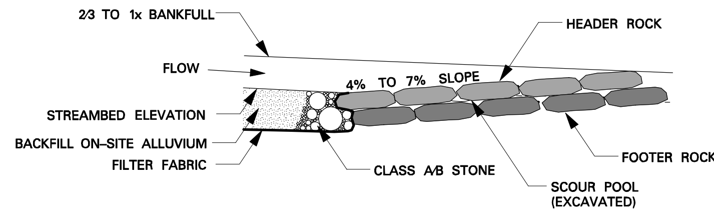
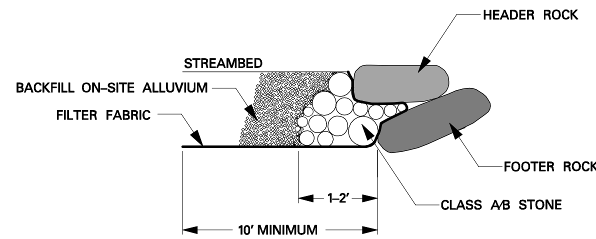
GRADE CONTROL J-HOOK VANE
FOR SAND/GRAVEL BED SYSTEMS



PLAN VIEW



PROFILE VIEW

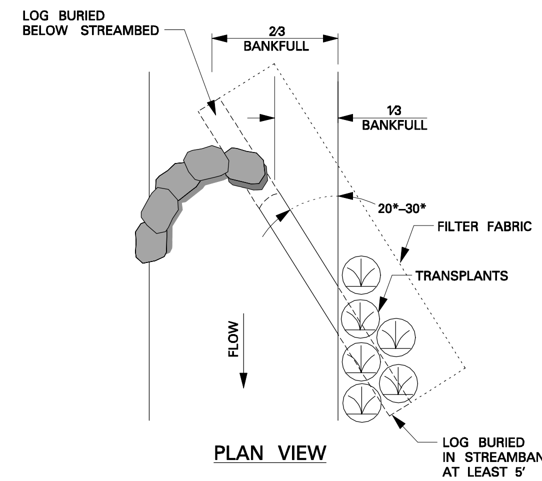


SECTION A - A

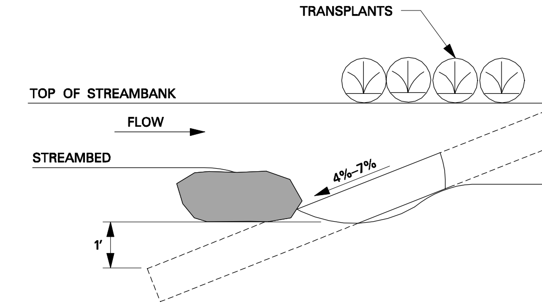
NOTES FOR ALL VANE STRUCTURES:

1. BOULDERS MUST BE AT LEAST 3' x 3' x 2'.
2. INSTALL FILTER FABRIC FOR DRAINAGE BEGINNING AT THE MIDDLE OF THE HEADER ROCKS AND EXTEND DOWNWARD TO THE DEPTH OF THE BOTTOM FOOTER ROCK, AND THEN UPSTREAM TO A MINIMUM OF TEN FEET.
3. DIG A TRENCH BELOW THE BED FOR FOOTER ROCKS AND PLACE FILL ON UPSTREAM SIDE OF VANE ARMS, BETWEEN THE ARMS AND STREAMBANK.
4. START AT BANK AND PLACE FOOTER ROCKS FIRST AND THEN HEADER (TOP) ROCK.
5. CONTINUE WITH STRUCTURE, FOLLOWING ANGLE AND SLOPE SPECIFICATIONS.
6. AN EXTRA BOULDER CAN BE PLACED IN SCOUR POOL FOR HABITAT IMPROVEMENT.
7. USE CLASS B STONE TO FILL GAPS ON UPSTREAM SIDE OF BOULDERS, AND CLASS A STONE TO FILL GAPS ON UPSTREAM SIDE OF CLASS B STONE.
8. AFTER ALL STONE HAS BEEN PLACED, FILL IN THE UPSTREAM SIDE OF THE STRUCTURE WITH ON-SITE ALLUVIUM TO THE ELEVATION OF THE TOP OF THE HEADER ROCK.

GRADE CONTROL J-HOOK VANE



PLAN VIEW



PROFILE VIEW

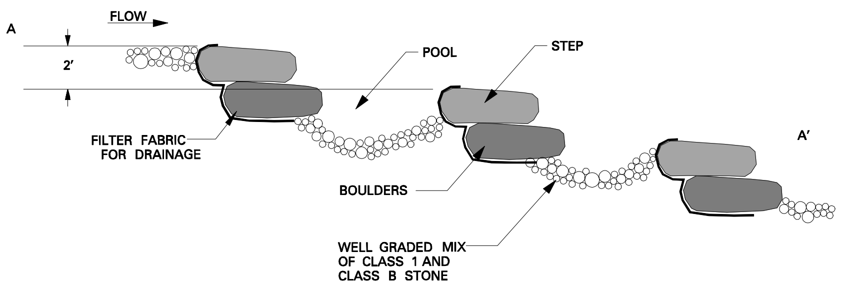
UPPER CANE CREEK				COMMISSARY BRANCH						
REACH 1&2		REACH 3&4		REACH 1		REACH 2		REACH 3		
RIFFLE	POOL	RIFFLE	POOL	RIFFLE	POOL	RIFFLE	POOL	RIFFLE	POOL	
8.4 ft	12.6 ft	7.2 ft	10.8 ft	9.0 ft	13.4 ft	8.4 ft	12.6 ft	6.8 ft	10.1 ft	WIDTH OF BANKFULL (Wbkf)
0.8 ft	1.4 ft	0.7 ft	1.2 ft	0.7 ft	1.5 ft	0.7 ft	1.4 ft	0.6 ft	1.1 ft	MINIMUM DEPTH (D)
0.8 ft	2.5 ft	0.7 ft	2.1 ft	1.0 ft	2.6 ft	0.8 ft	2.5 ft	0.8 ft	2.0 ft	MAXIMUM DEPTH (D-Max)
12	6.6	12	6.6	12	6.6	12	6.6	12	6.6	WIDTH TO DEPTH RATIO (Wbkf/D)
5.9 sq ft	8.0 ft/ft	4.3 sq ft	6.5 ft/ft	6.7 sq ft	13.4 ft/ft	5.9 sq ft	11.8 ft/ft	3.8 sq ft	7.6 ft/ft	BANKFULL AREA (Abkf)
3.2 ft	1.5	3.0 ft	1.5	5.2 ft	2.4 ft	4.9 ft	2.0 ft	3.9 ft	1.6 ft	BOTTOM WIDTH (Wb)

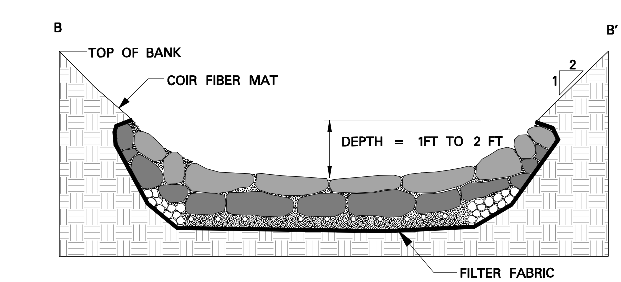
NOTES:

1. LOGS SHOULD BE AT LEAST 10" IN DIAMETER, RELATIVELY STRAIGHT, HARDWOOD, AND RECENTLY HARVESTED.
2. SOIL SHOULD BE COMPACTED WELL AROUND BURIED PORTIONS OF LOG.
3. TRANSPLANTS ARE PLACED ALONG THE TOP OF THE BANK OVER THE BURIED LOG VANE TO PROTECT AGAINST EROSION DURING HIGH FLOWS.
4. BOULDERS TO BE PLACED 1 TO 2 FEET APART.

STEP POOL CHANNEL

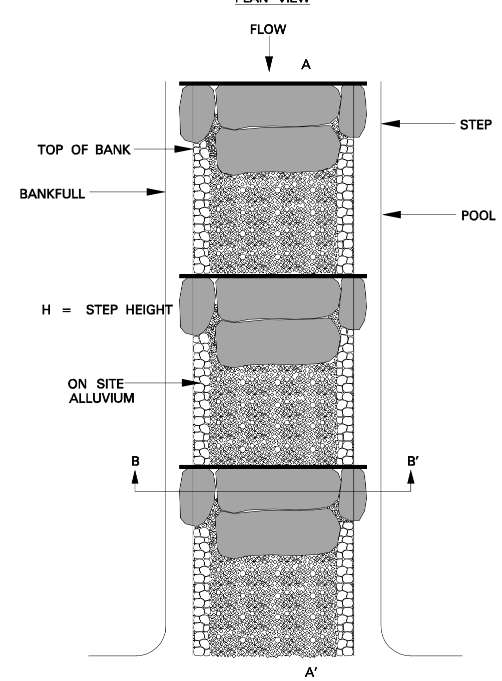
PROFILE VIEW A-A'



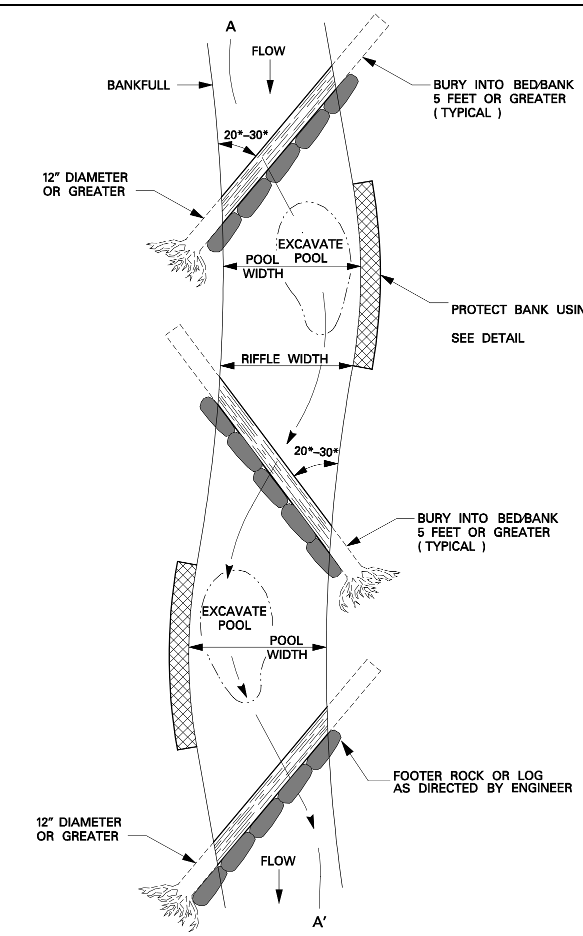


CROSS SECTION B-B'

PLAN VIEW

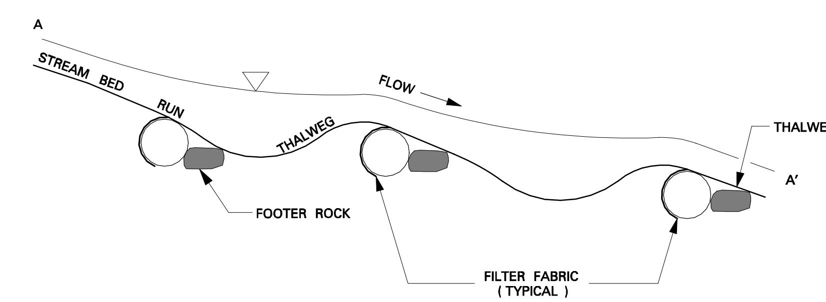


STREAM CHANNEL

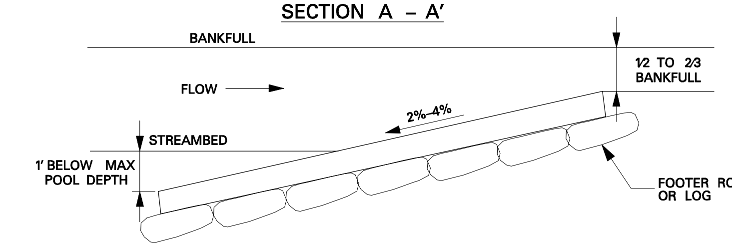


PLAN VIEW

LOG STEP /POOL



SECTION A - A'



PROFILE VIEW

NOTES:

1. LOGS WITHOUT ROOT MASS MAY BE USED IF APPROVED BY PROJECT ENGINEER.

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

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MENIFEE COUNTY, KENTUCKY

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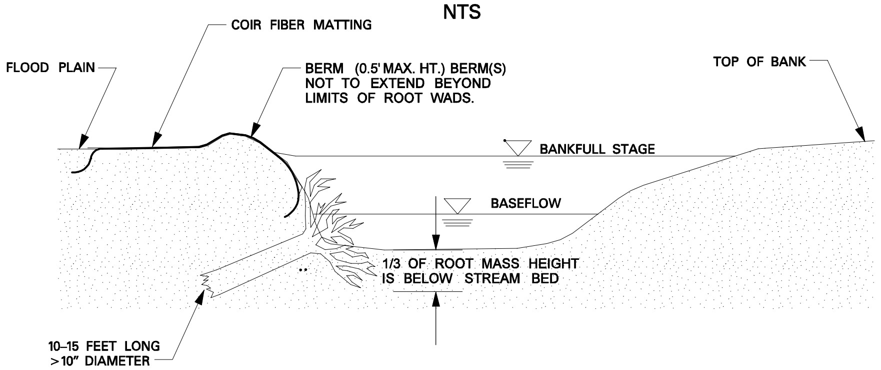
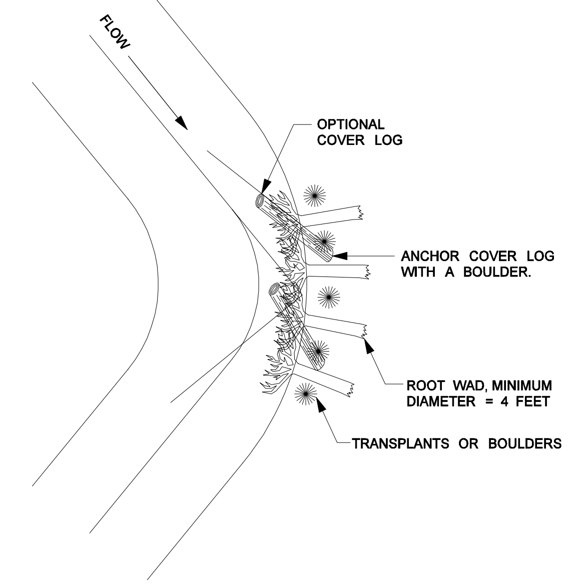
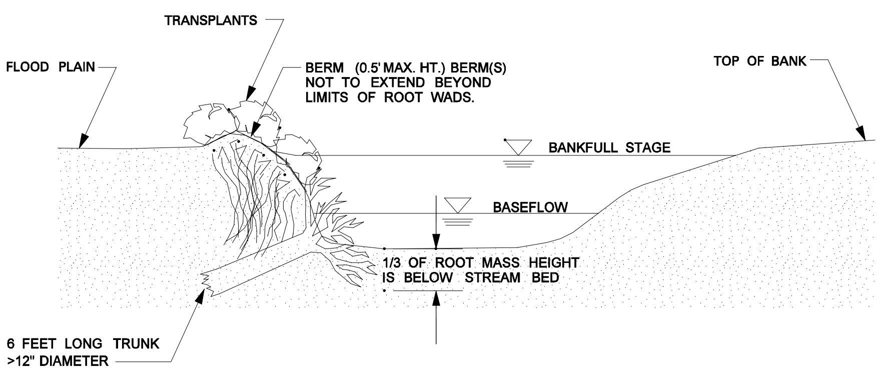
ROOT WADS WITHOUT TRANSPLANTS
CROSS SECTION VIEW
NTS



ROOT WADS
PLAN VIEW
NTS



ROOT WADS WITH TRANSPLANTS
CROSS SECTION VIEW
NTS



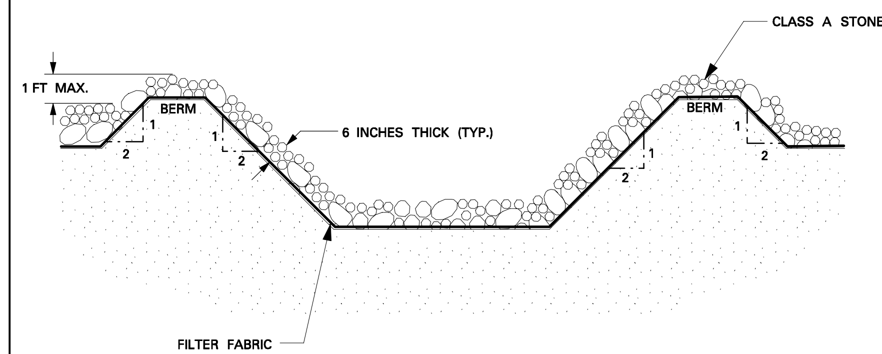
NOTES:

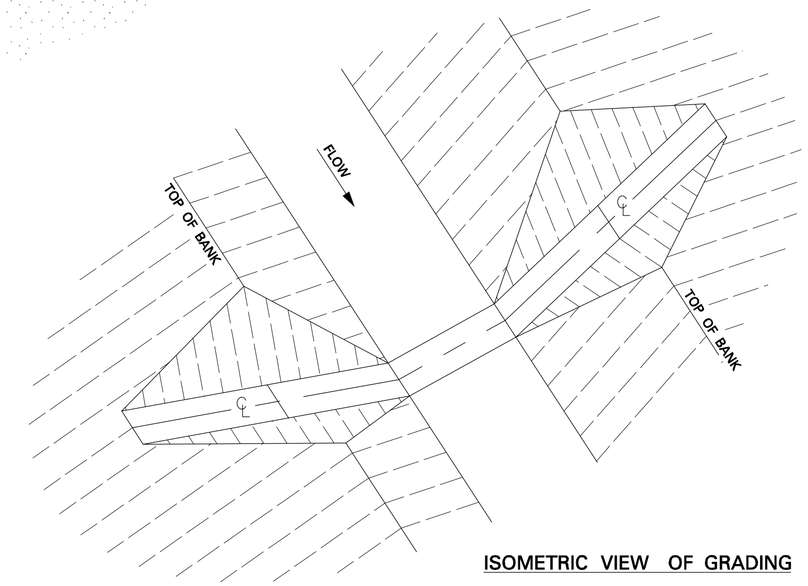
TRENCHING METHOD:
IF THE ROOT WAD CANNOT BE DRIVEN INTO THE BANK OR THE BANK NEEDS TO BE RECONSTRUCTED, THE TRENCHING METHOD SHOULD BE USED. THIS METHOD REQUIRES THAT A TRENCH BE EXCAVATED FOR THE LOG PORTION OF THE ROOT WAD. IN THIS CASE, A FOOTER LOG SHOULD BE INSTALLED UNDERNEATH THE ROOT WAD IN A TRENCH EXCAVATED PARALLEL TO THE BANK AND WELL BELOW THE STREAMBED. ONE-THIRD OF THE ROOT WAD SHOULD REMAIN BELOW NORMAL BASE FLOW CONDITIONS.

NOTES:

DRIVE POINT METHOD:
SHARPEN THE END OF THE LOG WITH A CHAINSAW BEFORE "DRIVING" IT INTO THE BANK. ORIENT ROOT WADS UPSTREAM SO THAT THE STREAM FLOW MEETS THE ROOT WAD AT A 90-DEGREE ANGLE, DEFLECTING THE WATER AWAY FROM THE BANK. A TRANSPLANT OR BOULDER SHOULD BE PLACED ON THE DOWNSTREAM SIDE OF THE ROOT WAD IF A BACK EDDY IS FORMED BY THE ROOT WAD. THE BOULDER SHALL BE APPROXIMATELY 4'X 3'X 2'.

FORD STREAM CROSSING



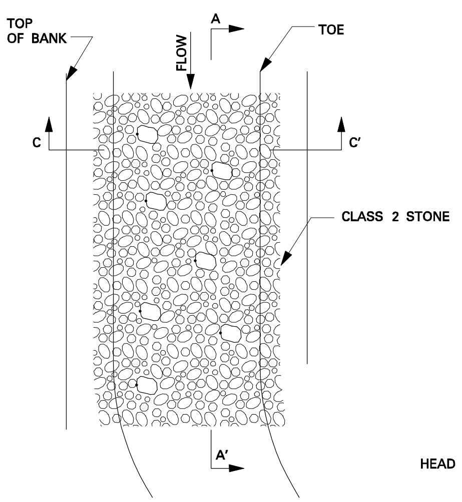


ISOMETRIC VIEW OF GRADING

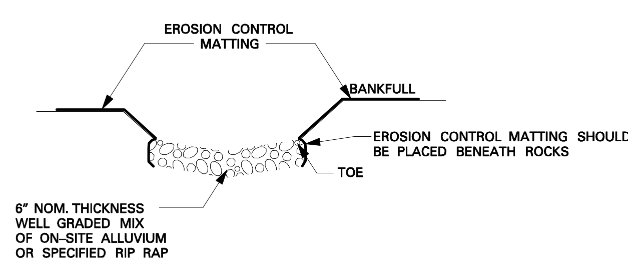
NOTES:

1. CONSTRUCT STREAM CROSSING WHEN FLOW IS LOW.
2. HAVE ALL NECESSARY MATERIALS AND EQUIPMENT ON-SITE BEFORE WORK BEGINS.
3. MINIMIZE CLEARING AND EXCAVATION OF STREAMBANKS. DO NOT EXCAVATE CHANNEL BOTTOM. COMPLETE ONE SIDE BEFORE STARTING ON THE OTHER SIDE.
4. INSTALL STREAM CROSSING AT RIGHT ANGLE TO THE FLOW.
5. GRADE SLOPES TO A 2:1 SLOPE. TRANSPLANT SOD FROM ORIGINAL STREAMBANK ONTO SIDE SLOPES.
6. MAINTAIN CROSSING SO THAT RUNOFF IN THE CONSTRUCTION ROAD DOES NOT ENTER EXISTING CHANNEL.
7. A STABILIZED PAD OF CLASS A STONE, 6 INCHES THICK, LINED WITH FILTER FABRIC FOR DRAINAGE SHALL BE USED OVER THE BERM AND ACCESS SLOPES.
8. WIDTH OF THE CROSSING SHALL BE SUFFICIENT TO ACCOMMODATE THE LARGEST VEHICLE CROSSING THE CHANNEL.
9. CONTRACTOR SHALL DETERMINE AN APPROPRIATE RAMP ANGLE ACCORDING TO EQUIPMENT UTILIZED.

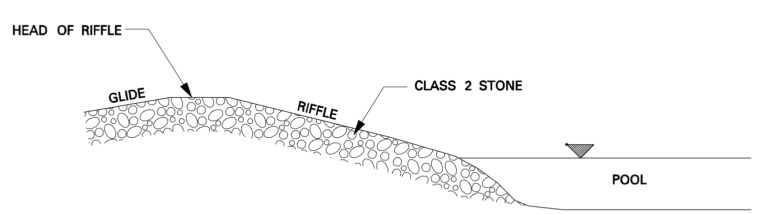
CONSTRUCTED RIFFLE



PLAN VIEW



SECTION C – C'



PROFILE A – A'

NOTES:

1. DIG A TRENCH BELOW THE BED FOR THE INVERT INSTALLATION.
2. PLACE CLASS 2 STONE INTO TRENCH APPROXIMATELY 2-4 INCHES BELOW CHANNEL INVERT ELEVATION.
3. FILL IN THE UPSTREAM SIDE OF THE STRUCTURE WITH ON-SITE ALLUVIUM (IF AVAILABLE) OTHERWISE USE WELL GRADED MIX OF CLASS A, CLASS B, AND #57 STONE TO THE INVERT ELEVATION OF THE CHANNEL.
4. UNDERCUT 6 FEET DOWN STREAM OF TAIL OF RIFFLE. BACK FILL ALL UNDERCUT AREAS WITH AN 8 – 10 INCH MIX OF ON-SITE ALLUVIUM.

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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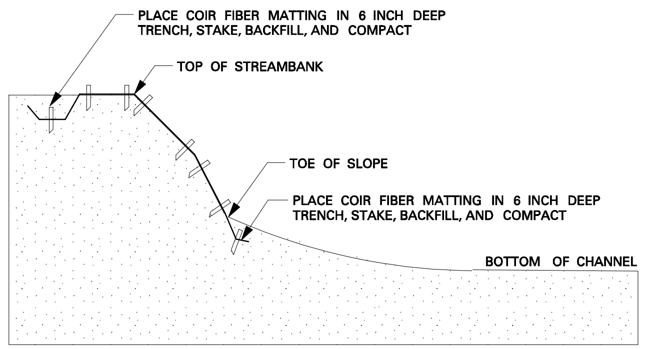
EROSION CONTROL MATTING

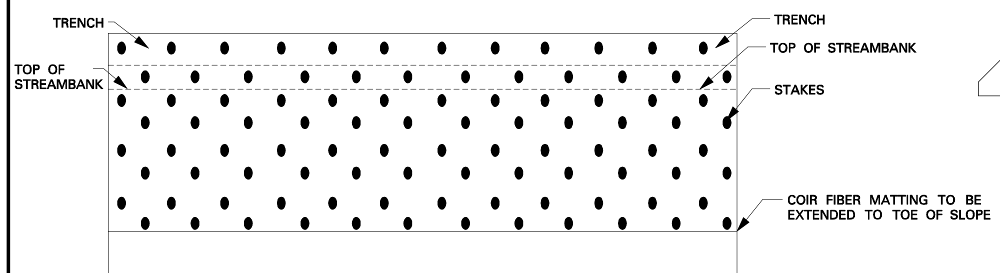


CROSS SECTION VIEW

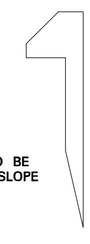
NOTES:

1. BANKS SHOULD BE SEEDED PRIOR TO PLACEMENT OF MATTING.
2. PLACE COIR FIBER MATTING ACCORDING TO PROPERTIES DESCRIBED BELOW.
3. MATTING STAKES SHOULD BE PLACED IN A DIAMOND SHAPED PATTERN.

MATRIX	100% COCONUT FIBER
WEIGHT	20oz/SY (678gm/m^2)
TENSILE STRENGTH	1348x626 lb/ft MINIMUM(1650.5x766.5kg/m)
ELONGATION	34%x38%
OPEN AREA(MEASURED)	50%
THICKNESS	0.30in MINIMUM (7.6mm)
FLEXABILITY(mg–cm)	65030x29590
RECOMMENDED FLOW	11FEET/SECOND(3.35m/s)
SIZE	6.6x164 (120SY) OR (100SM)
"C" FACTOR	0.002



PLAN VIEW

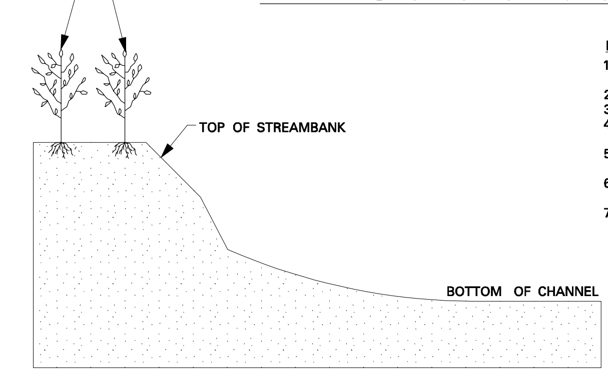


TYPICAL MATTING STAKE

THE WOOD STAKE SHALL BE THE NORTH AMERICAN GREEN ECO–STAKE OR APPROVED EQUAL WITH THE FOLLOWING DIMENSIONS:

LEG LENGTH	11.00 IN (27.94 CM)
HEAD WIDTH	1.25 IN (3.18 CM)
HEAD THICKNESS	0.40 IN (1.02 CM)
LEG WIDTH	0.60 IN (1.52 CM) (TAPERED TO POINT)
LEG THICKNESS	0.40 IN (1.02 CM)
TOTAL LENGTH	12.00 IN (30.48 CM)

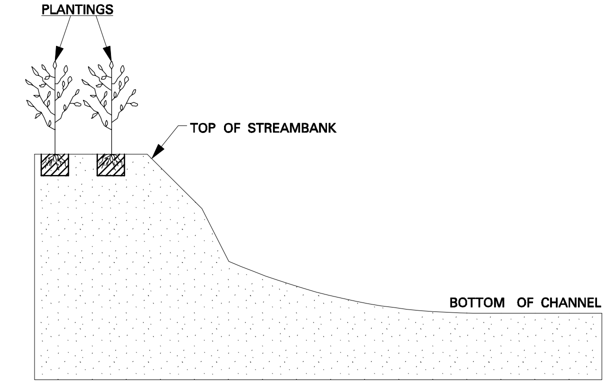
PLANTING SPECIFICATIONS



CROSS SECTION VIEW OF BARE ROOT PLANTING

NOTES:

1. PLANT BARE ROOT SHRUBS AND TREES TO THE WIDTH OF THE BUFFER AS SHOWN ON THE PLANS.
2. ALLOW FOR 6–10 FEET BETWEEN PLANTINGS, DEPENDING ON SIZE.
3. LOOSEN COMPACTED SOIL.
4. PLANT IN HOLES MADE BY A MATTOCK, DIBBLE, PLANTING BAR, OR OTHER APPROVED MEANS.
5. PLANT IN HOLES DEEP AND WIDE ENOUGH TO ALLOW THE ROOTS TO SPREAD OUT AND DOWN WITHOUT J–ROOTING.
6. KEEP ROOTS MOIST WHILE DISTRIBUTING OR WAITING TO PLANT BY MEANS OF WET CANVAS, BURLAP, OR STRAW.
7. HEEL–IN PLANTS IN MOIST SOIL OR SAWDUST IF NOT PROMPTLY PLANTED UPON ARRIVAL TO PROJECT SITE.

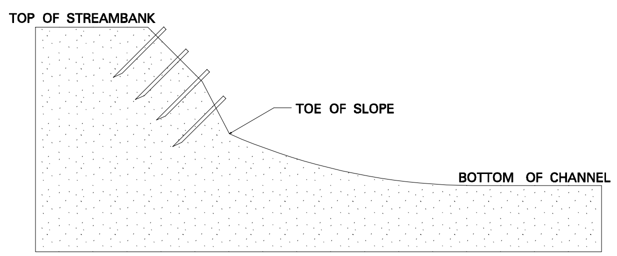


CROSS SECTION VIEW OF CONTAINER PLANTING

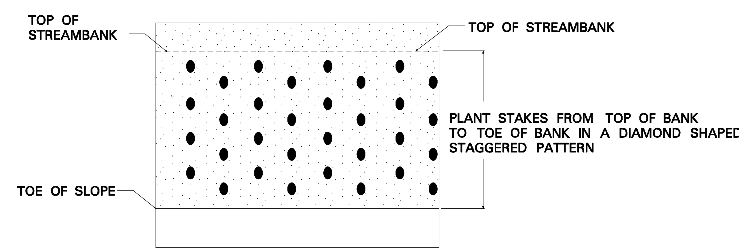
NOTES:

1. WHEN PREPARING THE HOLE FOR A POTTED PLANT OR SHRUB DIG THE HOLE 8 –12 INCHES LARGER THAN THE DIAMETER OF THE POT AND THE SAME DEPTH AS THE POT.
2. REMOVE THE PLANT FROM THE POT. LAY THE PLANT ON ITS SIDE IF NECESSARY TO REMOVE THE POT.
3. IF THE PLANT IS ROOTBOUND (ROOTS GROWING IN A SPIRAL AROUND THE ROOT BALL), MAKE VERTICAL CUTS WITH A KNIFE OR SPADE JUST DEEP ENOUGH TO CUT THE NET OF ROOTS. ALSO MAKE A CRISS–CROSS CUT ACROSS THE BOTTOM OF THE BALL.
4. PLACE THE PLANT IN THE HOLE.
5. FILL HALF OF THE HOLE WITH SOIL (SAME SOIL REMOVED FOR BACKFILL).
6. WATER THE SOIL TO REMOVE AIR POCKETS AND FILL THE REST OF THE HOLE WITH THE REMAINING SOIL.

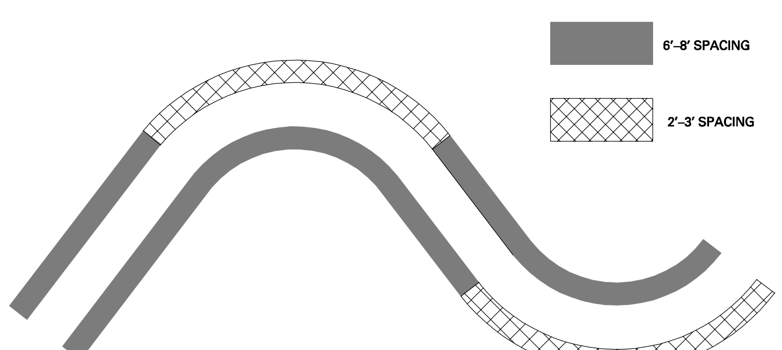
LIVE STAKING



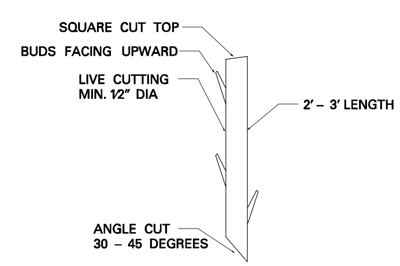
CROSS SECTION VIEW



PLAN VIEW



PLAN VIEW



LIVE STAKE DETAIL

NOTES:

1. STAKES SHOULD BE CUT AND INSTALLED ON THE SAME DAY.
2. DO NOT INSTALL STAKES THAT HAVE BEEN SPLIT.
3. STAKES MUST BE INSTALLED WITH BUDS POINTING UPWARDS.
4. STAKES SHOULD BE INSTALLED PERPENDICULAR TO BANK.
5. STAKES SHOULD BE 1/2 TO 2 INCHES IN DIAMETER AND 2 TO 3 FT LONG.
6. STAKES SHOULD BE INSTALLED LEAVING 1/5 OF STAKE ABOVE GROUND.

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

AS BUILT DATE: TBD
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CHECKED BY: FOGARTY
A&E FILE NO.: 110858
DATE: JAN. 19 2009

DETAIL SHEET

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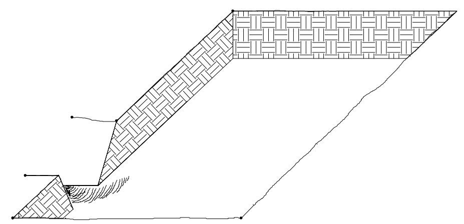
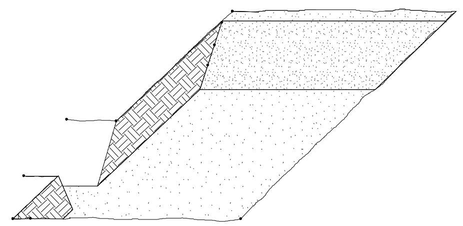
SEELING / LINER BAREROOT PLANTING DETAIL

HEALING IN

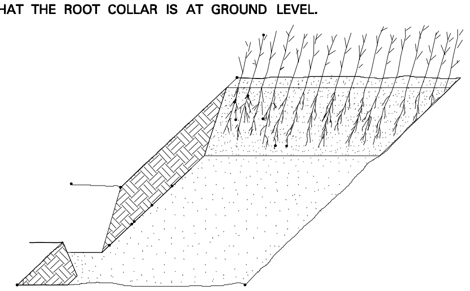
1. LOCATE A HEALING-IN SITE IN A SHADY, WELL PROTECTED AREA.
2. EXCAVATED A FLAT BOTTOM TRENCH 12 INCHES DEEP AND PROVIDE DRAINAGE.



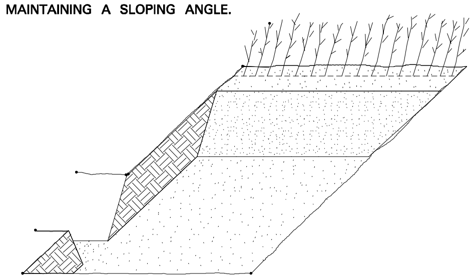
3. BACKFILL THE TRENCH WITH 2 INCHES OF WELL ROTTED SAWDUST. PLACE A 2 INCH LAYER OF WELL ROTTED SAWDUST AT A SLOPING ANGLE AT ONE END OF THE TRENCH.



4. PLACE A SINGLE LAYER OF PLANTS AGAINST THE SLOPING END SO THAT THE ROOT COLLAR IS AT GROUND LEVEL.

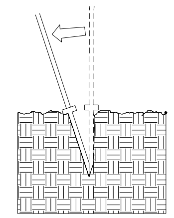


5. PLACE A 2 INCH LAYER OF WEL ROTTED SAWDUST OVER THE ROOTS MAINTAINING A SLOPING ANGLE.

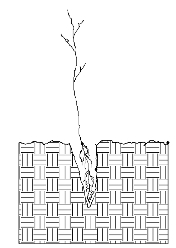


6. REPEAT LAYERS OF PLANTS AND SAWDUST AS NECESSARY AND WATER THOROUGHLY.

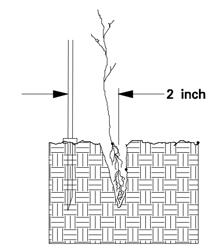
DIBBLE PLANTING METHOD USING THE KBC PLANTING BAR



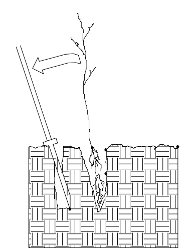
1. INSERT PLANTING BAR AS SHOWN AND PULL HANDLE TOWARD PLANTER.



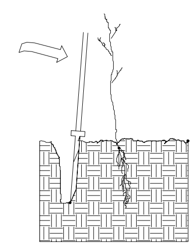
2. REMOVE PLANTING BAR AND PLACESEEDING AT CORRECT DEPTH.



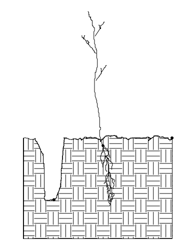
3. INSERT PLANTING BAR 2 INCHES TOWARD PLANTER FROM SEEDING.



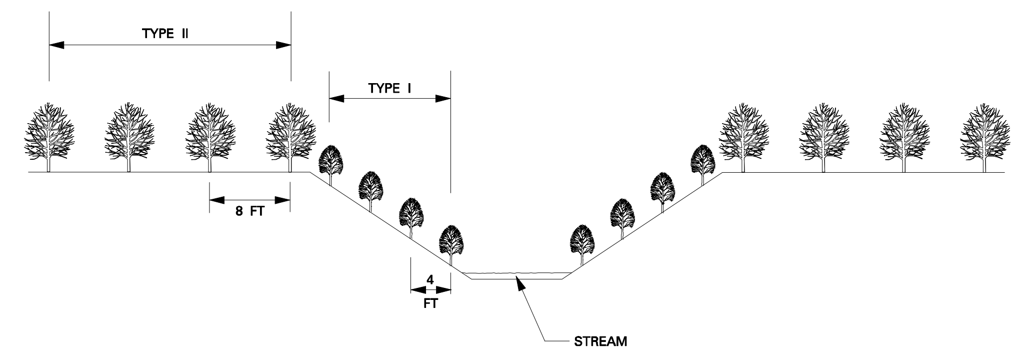
4. PULL HANDLE OF BAR TOWARD PLANTER, FIRMING SOIL AT BOTTOM.



5. PUSH HANDLE FORWARD FIRMING SOIL AT TOP.



6. LEAVE COMPATION HOLE OPEN. WATER THOROUGHLY.



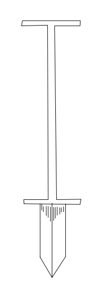
PLANTING NOTES:

PLANTING BAG

DURING PLANTING, SEEDLINGS SHALL BE KEPT IN A MOIST CANVAS BAG OR SIMILAR CONTAINER TO PREVENT THE ROOT SYSTEMS FROM DRYING.

KBC PLANTING BAR

PLANTING BAR SHALL HAVE A BLADE WITH A TRIANGULAR CROSS SECTION, AND SHALL BE 12 INCHES LONG, 4 INCHES WIDE AND 1 INCH THICK AT CENTER.



ROOT PRUNING

ALL SEEDLINGS SHALL BE ROOT PRUNED, IF NECESSARY, SO THAT NO ROOTS EXTEND MORE THAN 10 INCHES BELOW THE ROOT COLLAR.

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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QUANTITIES

Item	Description	Quantity	Unit
C	Mobilization	1	LS
D	Silt Fence	2,000	FT
F	Mulch	250	BALES
F	Temporary Seed	1,100	LBS
G	Permanent Seed	150	LBS
F	Spreading of Seed[1]	3	ACRES
H	Excavation, Fill and Grading	7,500	CU YARDS
H	Roughing of Soil[2]	2	ACRES
H	Clearing	2	ACRES
H	Grubbing	2	ACRES
I	Boulders	300	TONS
I	Class A/B Stone	550	TONS
K	Filter Fabric, Type II	1,100	SY
J	Root Wads	50	ROOT WADS
J	Logs	115	LOGS
L	Erosion Mat	7,000	SY
N	Live Stakes	9,350	STAKES
S	Bare–root Planting	3,750	STEMS

[1]Includes stream banks, road areas and staging areas
[2]Includes road areas and staging areas

STRUCTURE QUANTITIES

Structure	Quantity
Log Cross Vanes	4
Rock Cross Vanes	3
Constructed Riffle	10
Rock Step Pool	35
Log Step Pool	20
Log J–Hook Vanes	23
Rock J–Hook Vanes	5
Rock Toe Protection	4
Ford Road Crossing	3
Rootwads[3]	15

[3]Includes 14 different locations

CONSTRUCTION SEQUENCE

The following construction sequence shall be used during construction

1. Mobilize equipment and materials to the site and set up staging areas and erosion control measures
2. Restrict construction traffic to the areas denoted as haul roads and staging areas.
3. Silt fencing shall be placed around staging and temporary stockpile areas. Once construction is completed at a particular working area, temporary seeding and mulching shall be applied before progressing to a new area. Any disturbed areas shall have temporary or permanent ground cover applied within 15 working days or 30 calendar days, whichever is sooner, following the completion of grading activities in that area.
4. The sequence in which the mitigation area is constructed is to be decided by the Contractor. Contractor should finish one reach before moving on to the next. However, all newly constructed, relocated channel sections shall be stabilized and covered with erosion control matting by the end of the working day.
5. In–stream structures shall be constructed in the wet. Activity within the stream shall be kept to a minimum. Equipment will only enter the stream as necessary.
6. All disturbed areas shall be seeded and mulched before leaving the project site.
7. Prior to demobilization of equipment from site, ensure that the site is free from trash and leftover materials.
8. Demobilize equipment from site.
9. Plant riparian vegetation and permanent (pasture and riparian) seeding at the appropriate time of year.

	COMMISSARY BRANCH						UPPER CANE CREEK			
PARAMETERS	REACH 1		REACH 2		REACH 3		REACH 1 & 2		REACH 3 & 4	
	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
Drainage Area, DA (sq mi)	0.32		0.26		0.17		0.26		0.13	
Stream Type (Rosgen)	B4		B4		A4		B4		B4	
Bankfull Discharge, Qbkf (csf)	30.7	30.7	26.1	26.1	18.7	18.7	26.1	26.1	15.1	15.1
Bankfull Riffle XSEC Area, Abkf (sq ft)	6.7	6.7	5.9	5.9	3.8	3.8	5.9	5.9	4.3	4.3
Bankfull Mean Velocity, Vbkf (ft/s)	4.6	4.6	4.4	4.4	4.9	4.9	4.4	4.4	3.5	3.5
Bankfull Riffle Width, Wbkf (ft)	9.0	9.0	8.4	8.4	6.8	6.8	8.4	8.4	7.2	7.2
Bankfull Riffle Mean Depth, Dbkf (ft)	0.7	0.7	0.7	0.7	0.6	0.6	0.7	0.7	0.6	0.6
Width to Depth Ratio, W/D (ft/ft)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Width Floodprone Area, Wfpa (ft)	14	20	14	18	10	15	14	18	10	15
Entrenchment Ratio, Wfpa/Wbkf (ft/ft)	1.6	2.2	1.7	2.1	1.5	2.2	1.7	2.1	1.4	2.1
Riffle Max Depth @ bkf, Dmax (ft)	0.8	1.0	0.8	0.8	0.6	0.8	0.8	0.8	0.7	0.7
Riffle Max Depth Ratio, Dmax/Dbkf	1.1	1.3	1.1	1.1	1.1	1.4	1.1	1.1	1.1	1.1
Max Depth @ top of bank, Dmaxtob (ft)	0.8	1.0	0.8	0.8	0.6	0.8	0.8	0.8	0.7	0.7
Bank Height Ratio, Dtob/Dmax (ft/ft)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Meander Length, Lm (ft)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meander Length Ratio, Lm/Wbkf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Radius of Curvature, Rc (ft)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Rc Ratio, Rc/Wbkf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Belt Width, Wblt (ft)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meander Width Ratio, Wblt/Wbkf	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sinuosity, K	1.20	1.20	1.20	1.20	1.00	1.00	1.20	1.20	1.00	1.00
Valley Slope, Sval (ft/ft)	0.0394	0.0394	0.0394	0.0394	0.0830	0.0830	0.0280	0.0280	0.0530	0.0530
Channel Slope, Schan (ft/ft)	0.0328	0.0328	0.0328	0.0328	0.0830	0.0830	0.0233	0.0233	0.0530	0.0530
Slope Riffle, Srif (ft/ft)	0.0361	0.0591	0.0361	0.0591	0.0913	0.1494	0.0257	0.0420	0.0583	0.0954
Riffle Slope Ratio, Srif/Schan	1.1	1.8	1.1	1.8	1.1	1.8	1.1	1.8	1.1	1.8
Slope Pool, Spool (ft/ft)	0.0000	0.0131	0.0000	0.0131	0.0000	0.0332	0.0000	0.0093	0.0000	0.0212
Pool Slope Ratio, Spool/Schan	0.00	0.40	0.00	0.40	0.00	0.40	0.00	0.40	0.00	0.40
Pool Max Depth, Dmaxpool (ft)	1.5	2.6	1.4	2.5	1.1	2.0	1.4	2.5	1.2	2.1
Pool Max Depth Ratio, Dmaxpool/Dbkf	2.0	3.5	2.0	3.5	2.0	3.5	2.0	3.5	2.0	3.5
Pool Width, Wpool (ft)	9.9	13.4	9.3	12.6	7.4	10.1	9.3	12.6	7.9	10.8
Pool Width Ratio, Wpool/Wbkf	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5	1.1	1.5
Pool Width/Depth Ratio	6.6	5.1	6.6	5.1	6.6	5.1	6.6	5.1	6.6	5.1
Pool Area, Apool (ft/ft)	8.7	13.4	7.7	11.8	4.9	7.6	7.7	11.8	5.6	8.6
Pool Area Ratio, Apool/Abkf	1.3	2.0	1.3	2.0	1.3	2.0	1.3	2.0	1.3	2.0
Riffle Length, Lriffle (ft)	9.0	26.9	8.4	25.2	6.8	20.3	8.4	25.2	7.2	21.5
Riffle Length Ratio, Lriffle/Wbkf (ft)	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0	1.0	3.0
Pool–Pool Spacing, Lps (ft)	13.4	44.8	12.6	42.1	10.1	33.8	12.6	42.1	10.8	35.9
Pool–Pool Spacing Ratio, Lps/Wbkf	1.5	5.0	1.5	5.0	1.5	5.0	1.5	5.0	1.5	5.0
Pool Length. Lpool (ft)	4.5	13.4	3.4	10.1	3.4	10.1	4.2	12.6	3.6	10.8
Pool Length Ratio, Lpool/Wbkf (ft)	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5	0.5	1.5
d16 (mm)	8.5		8.5		5.2		12.0		15.0	
d35 (mm)	19.0		19.0		20.0		22.0		22.0	
d50 (mm)	32.0		32.0		31.0		31.0		29.0	
d84 (mm)	83		83		100		69.0		71.0	
d95 (mm)	130		130		160		92.0		90.0	

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

DESIGN PARAMETERS

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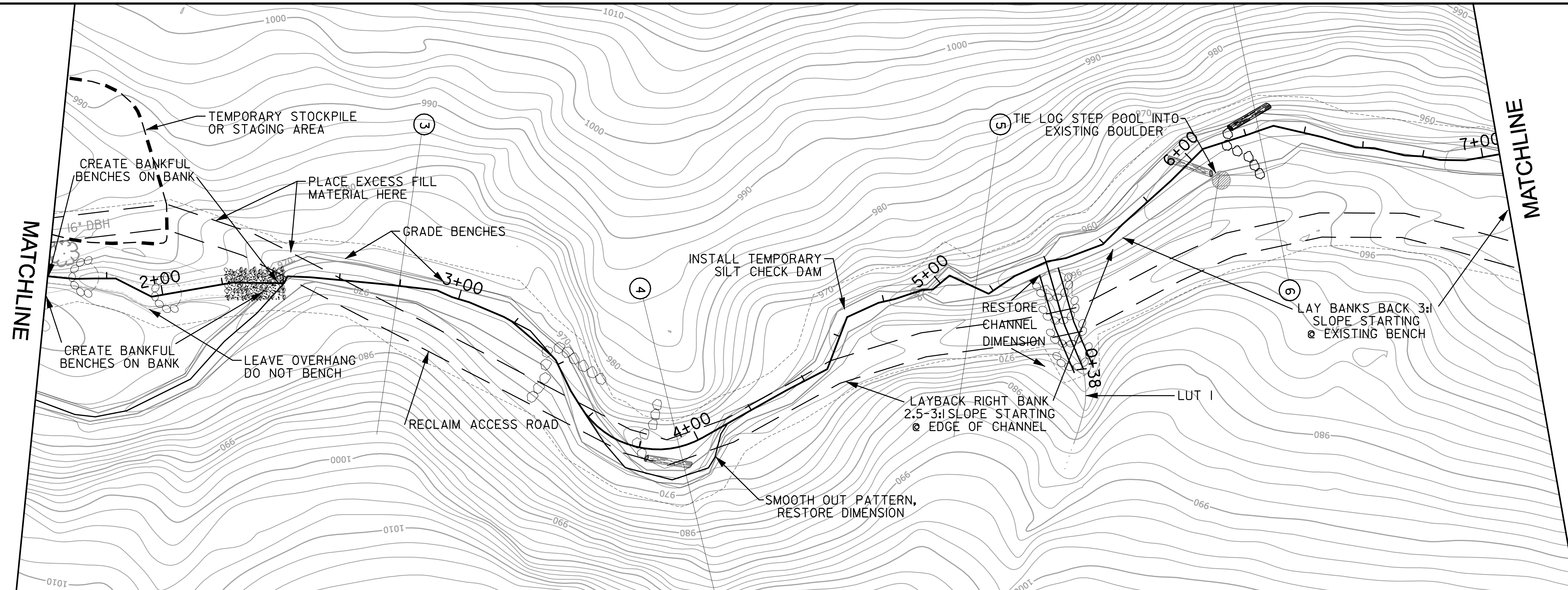

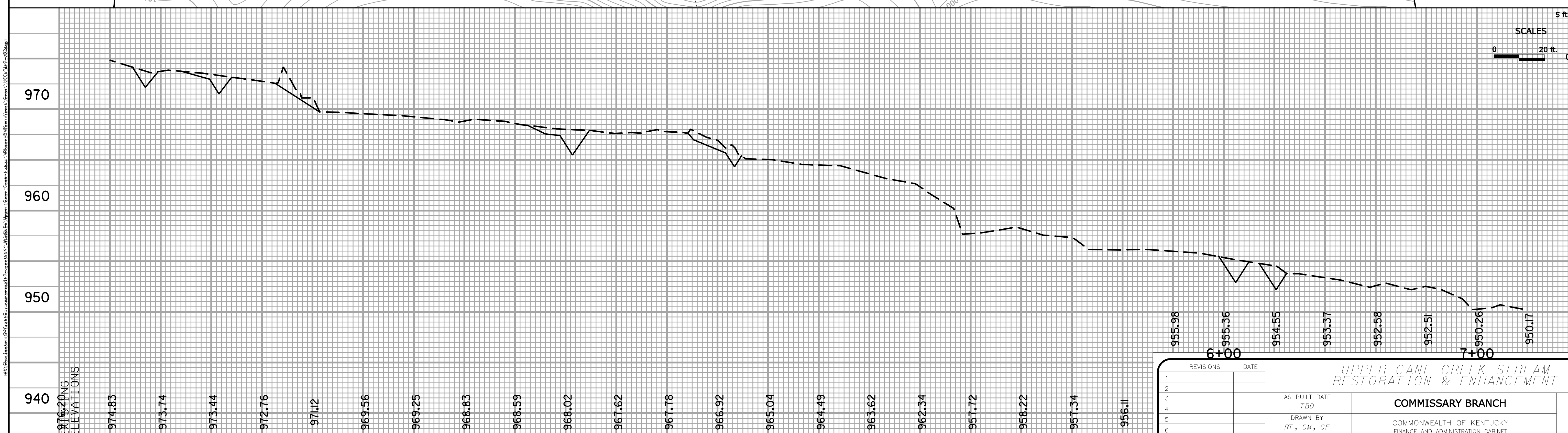

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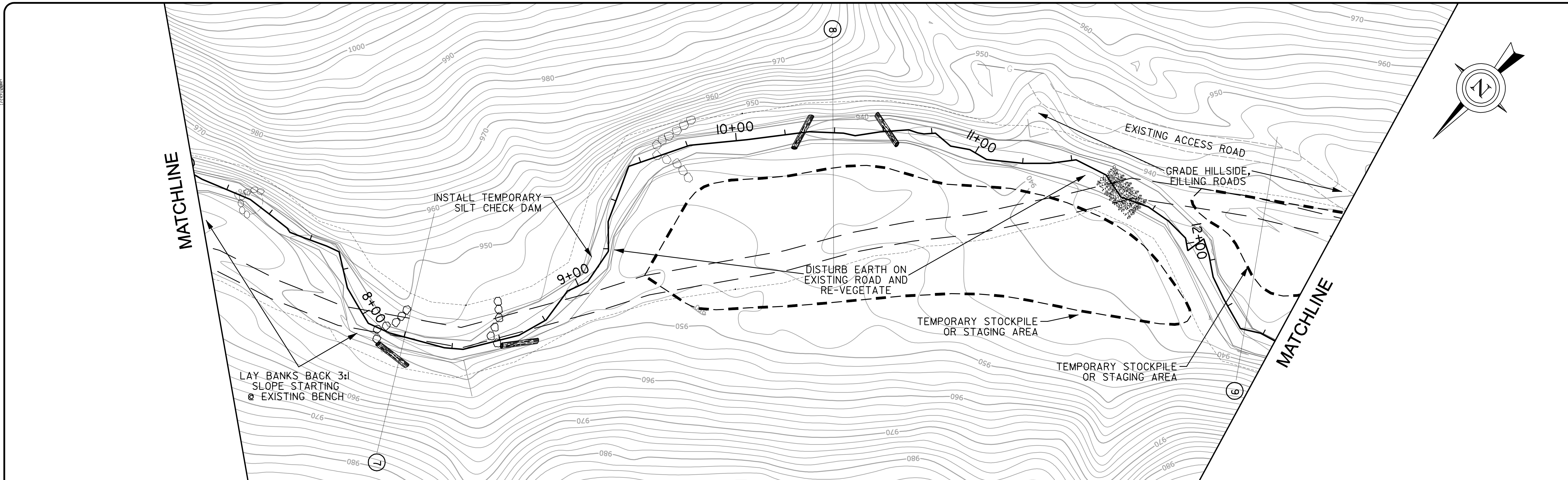

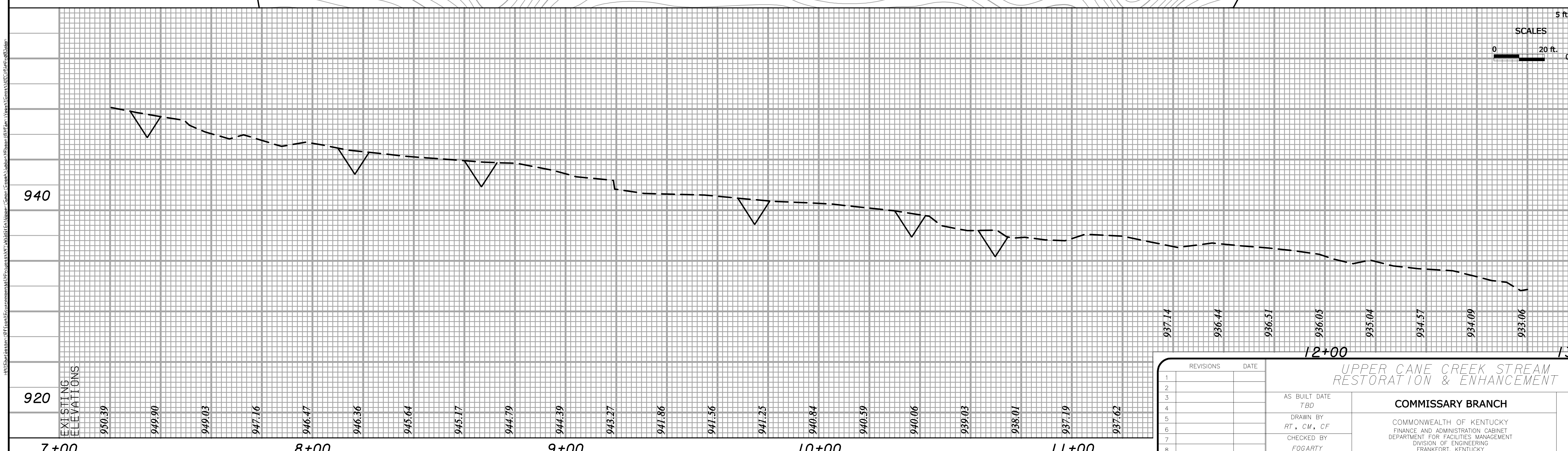

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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FOGARTY
A&E FILE NO.
110858
DATE
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COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

Baker
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5088 West Washington Street
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(304)-769-0821 Office
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KENTUCKY FISH AND WILDLIFE
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Baker
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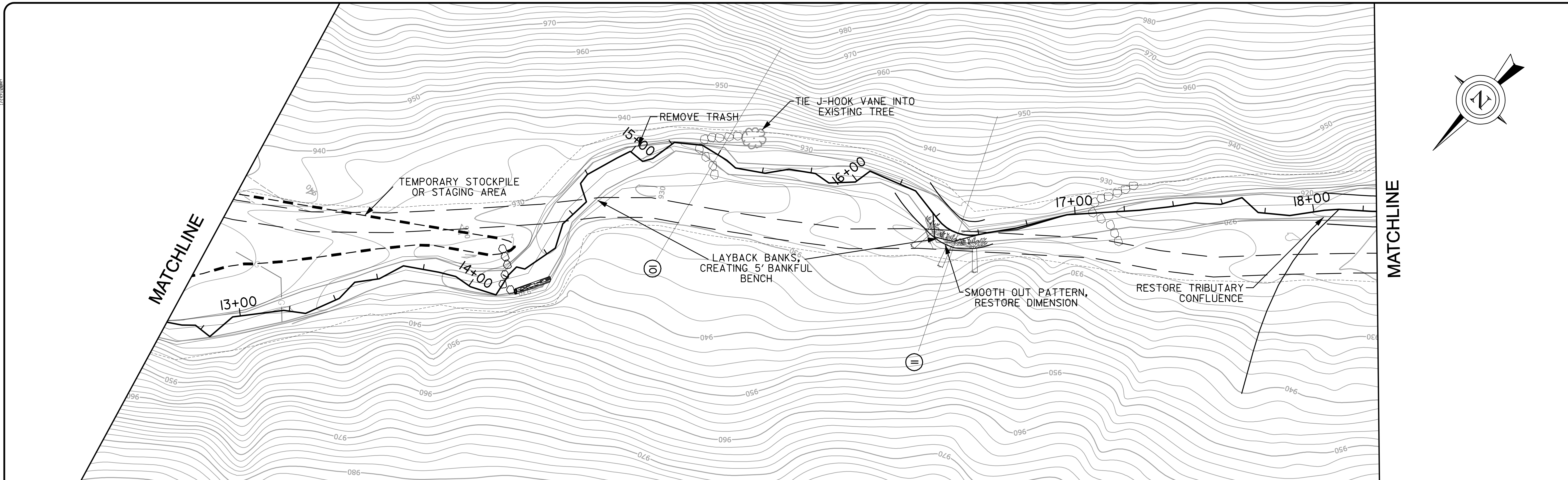

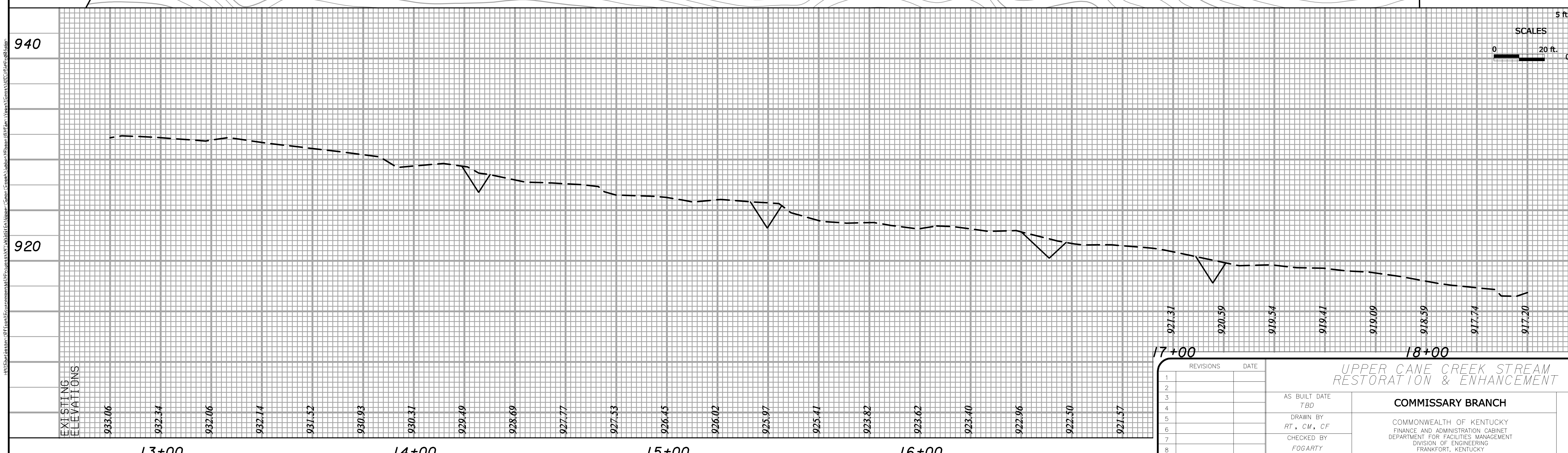

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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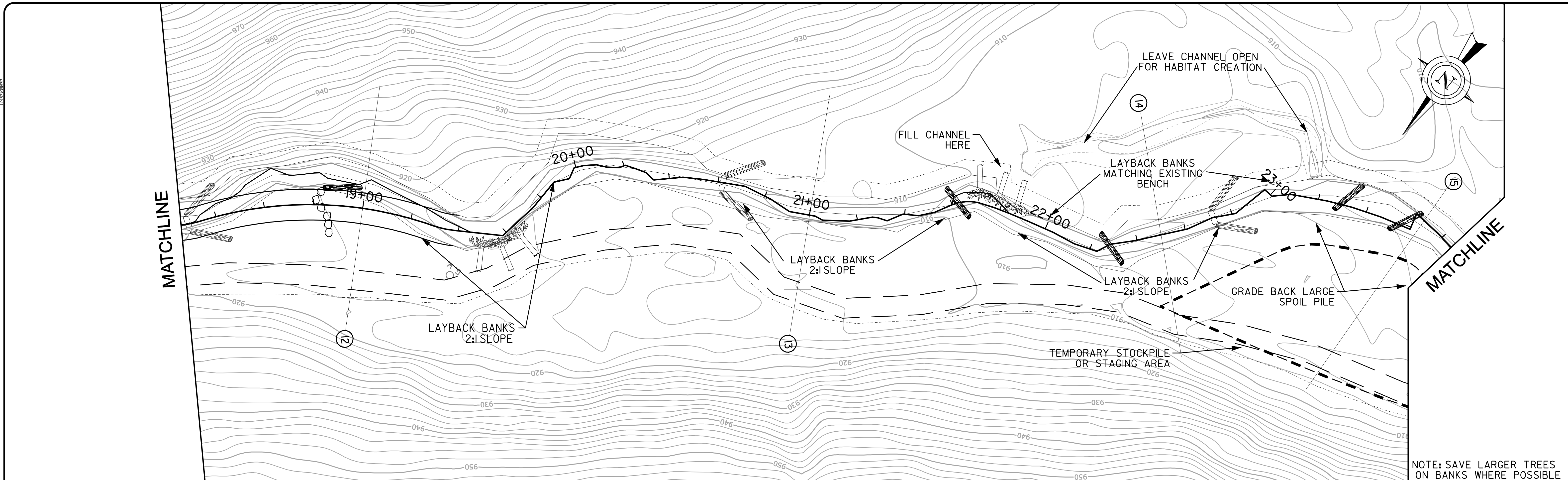

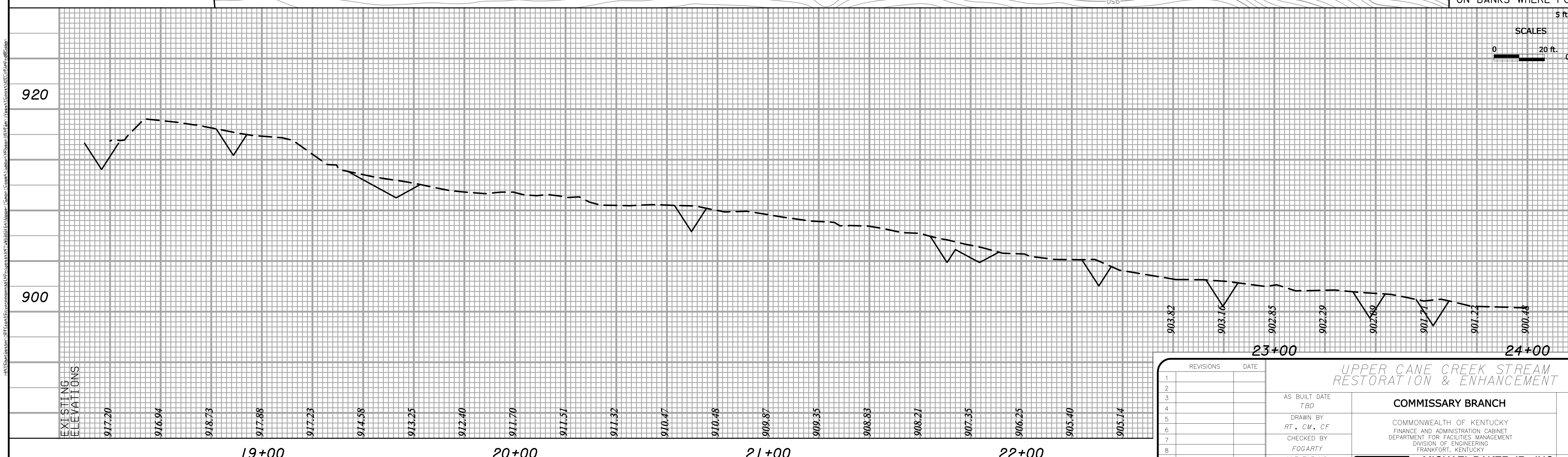

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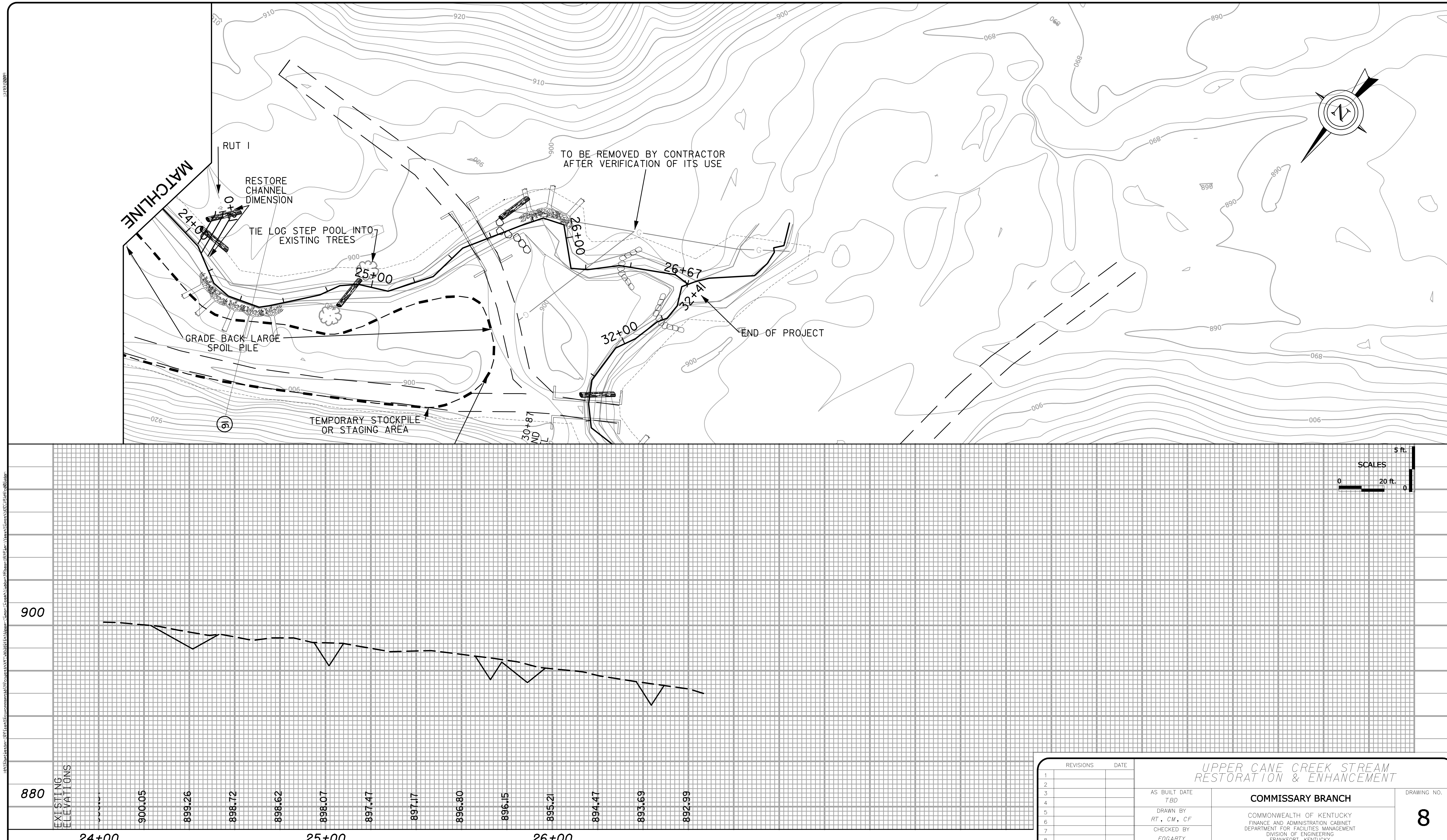

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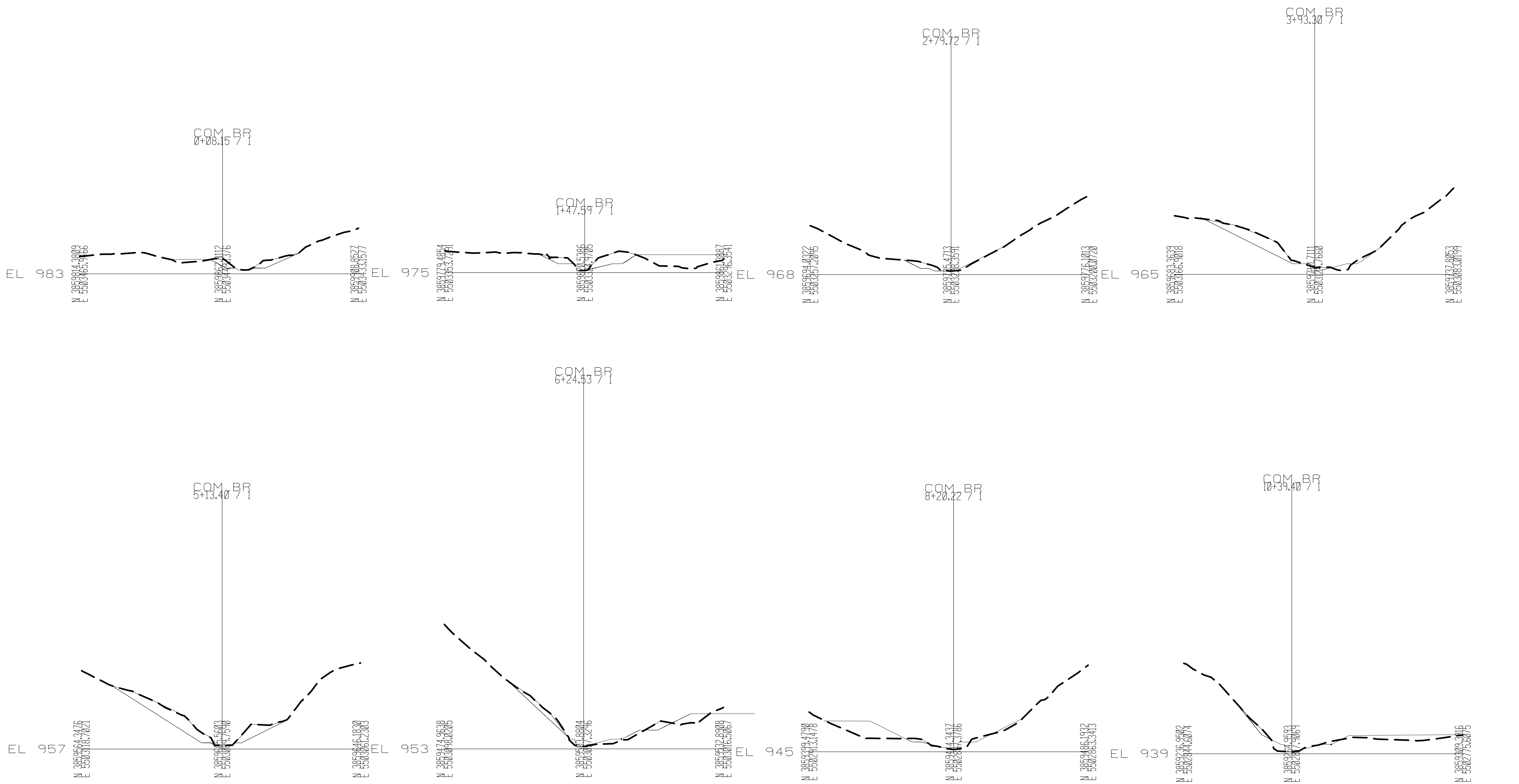

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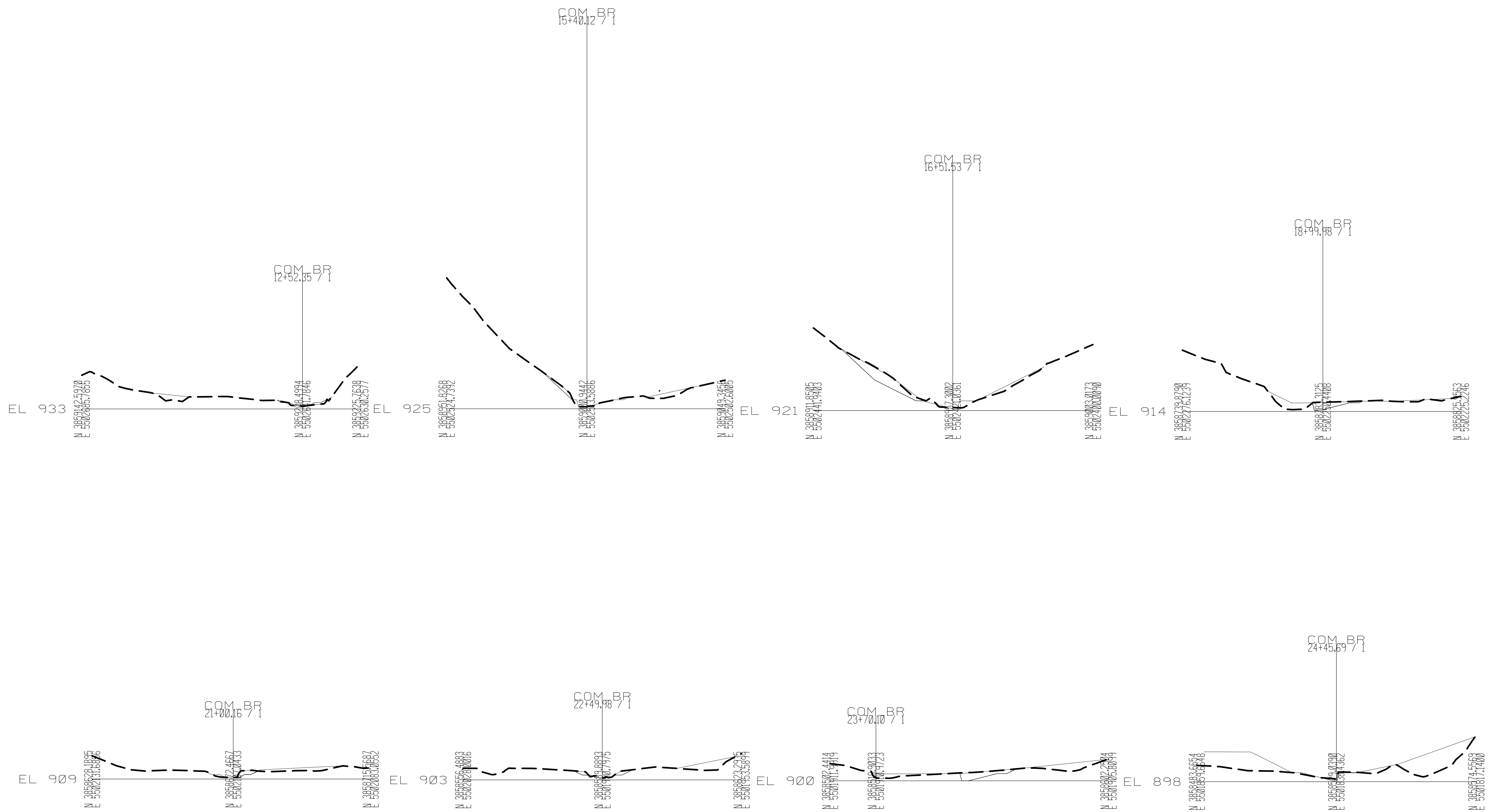

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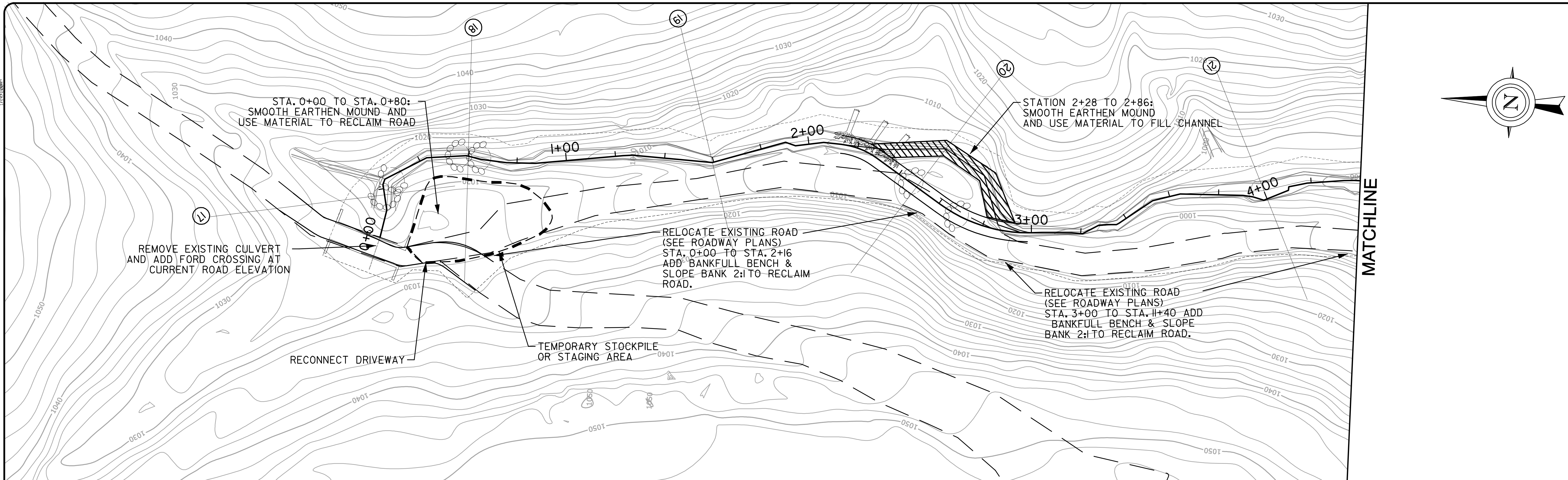

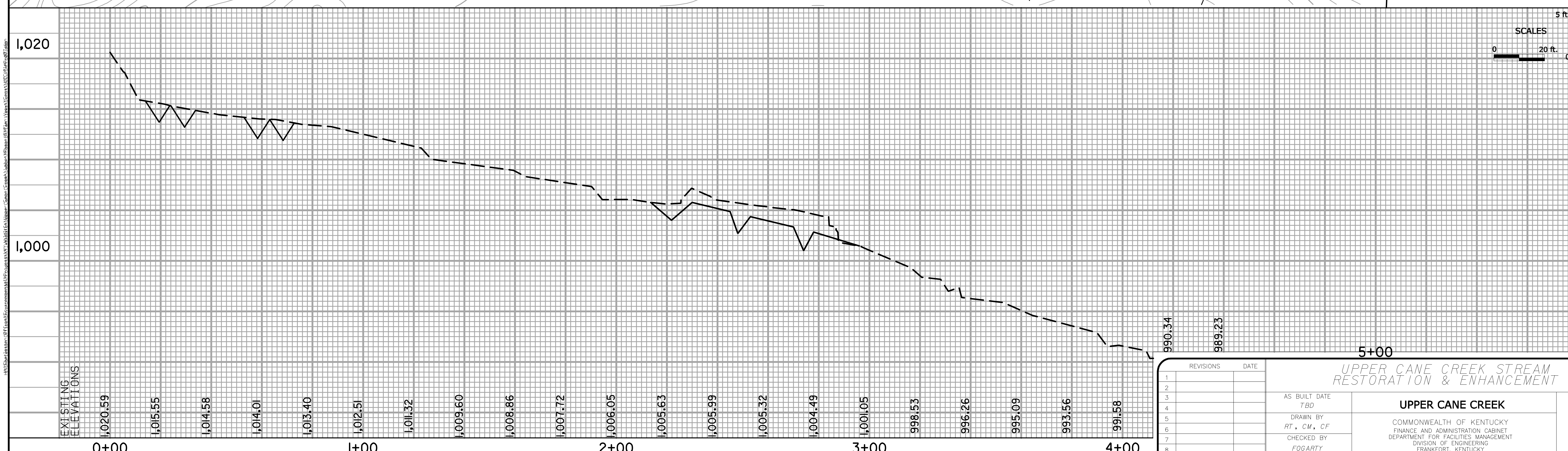

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UPPER CANE CREEK

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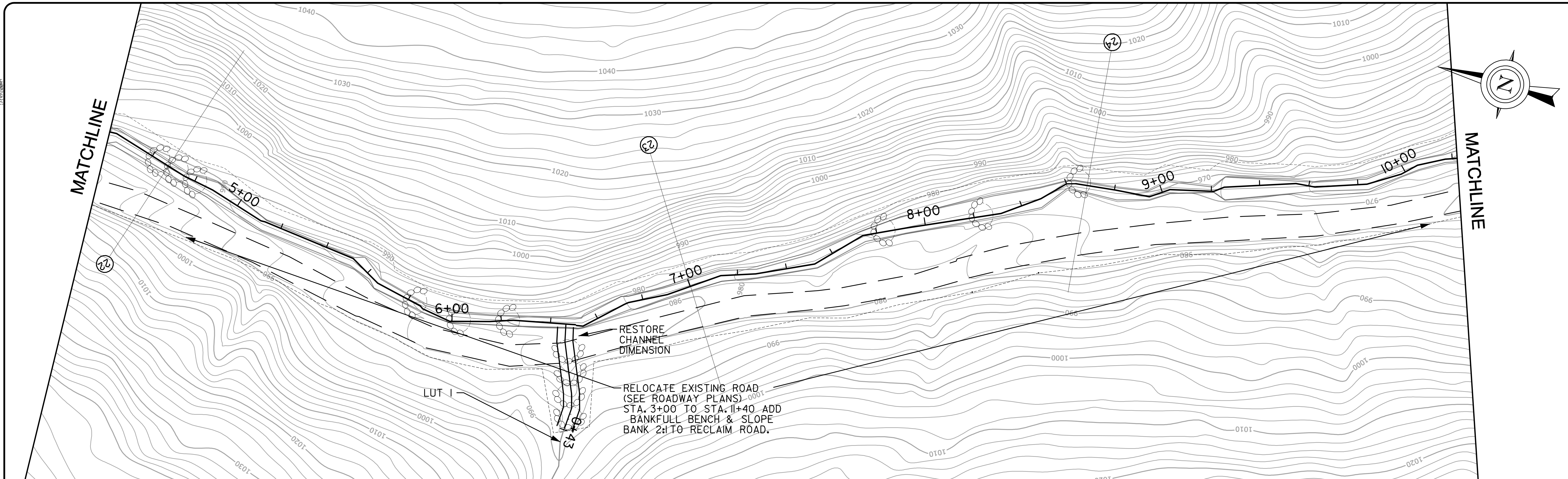

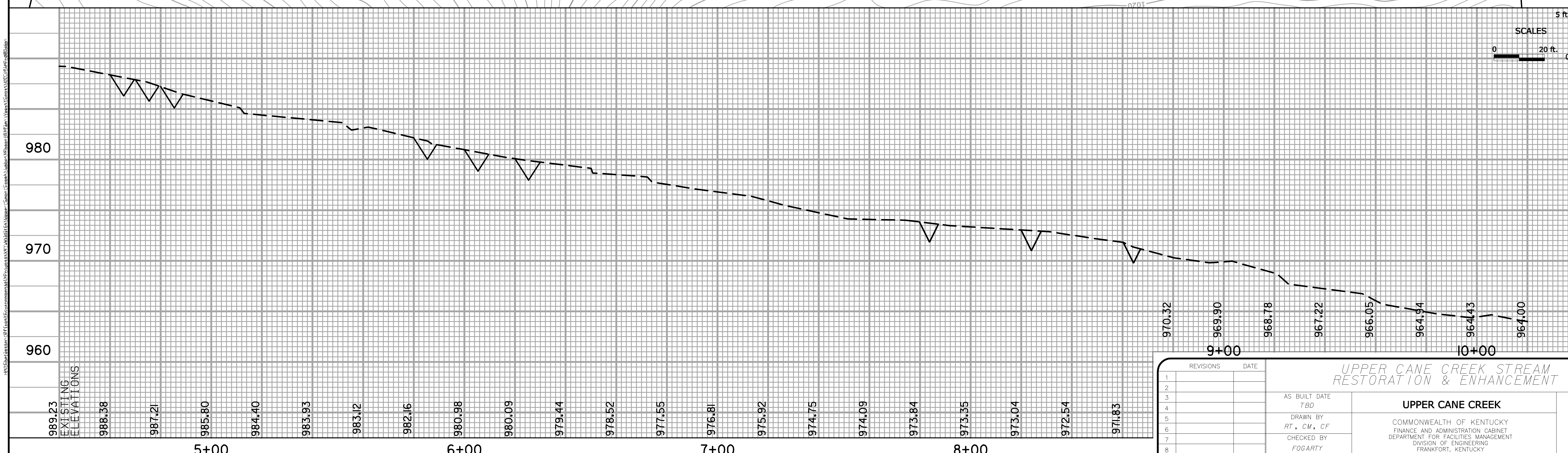

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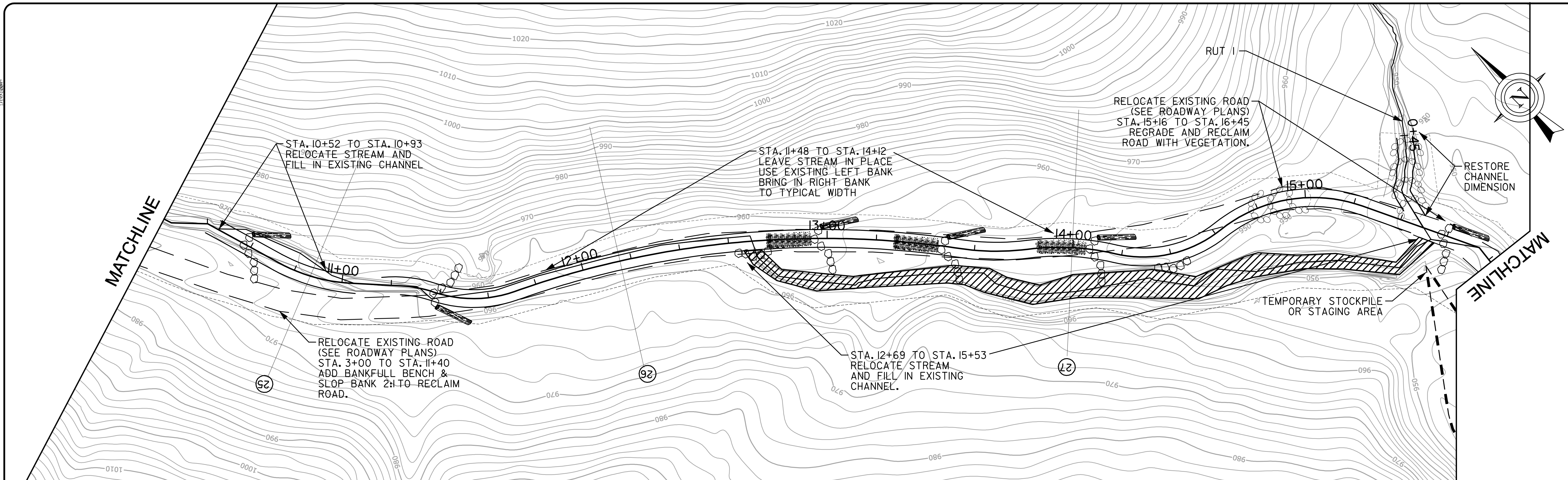

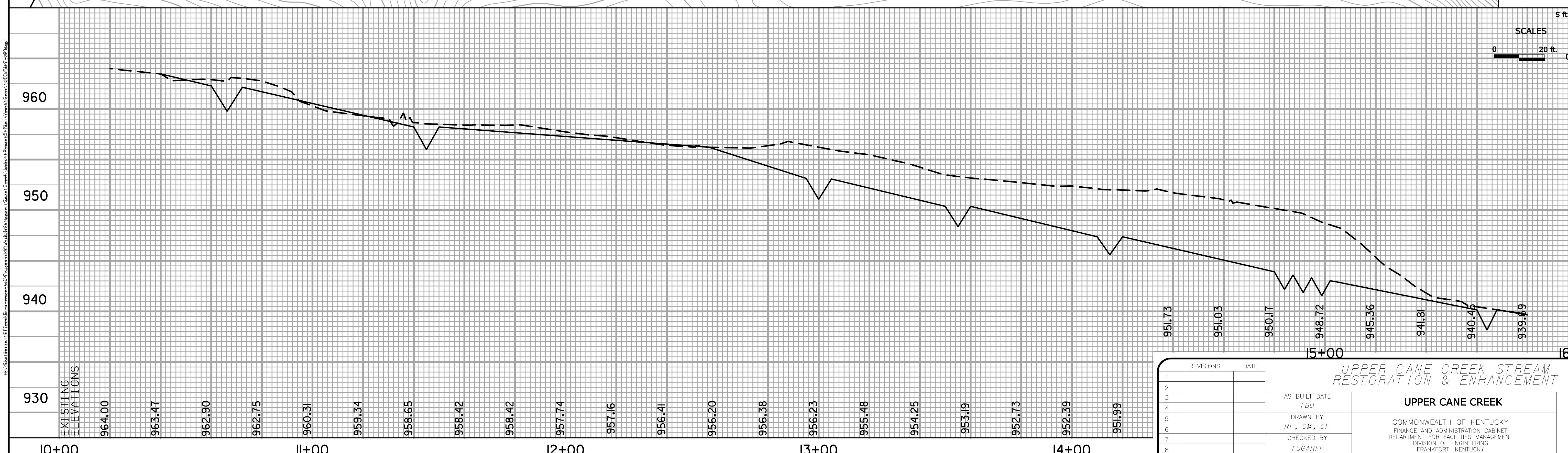

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

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UPPER CANE CREEK

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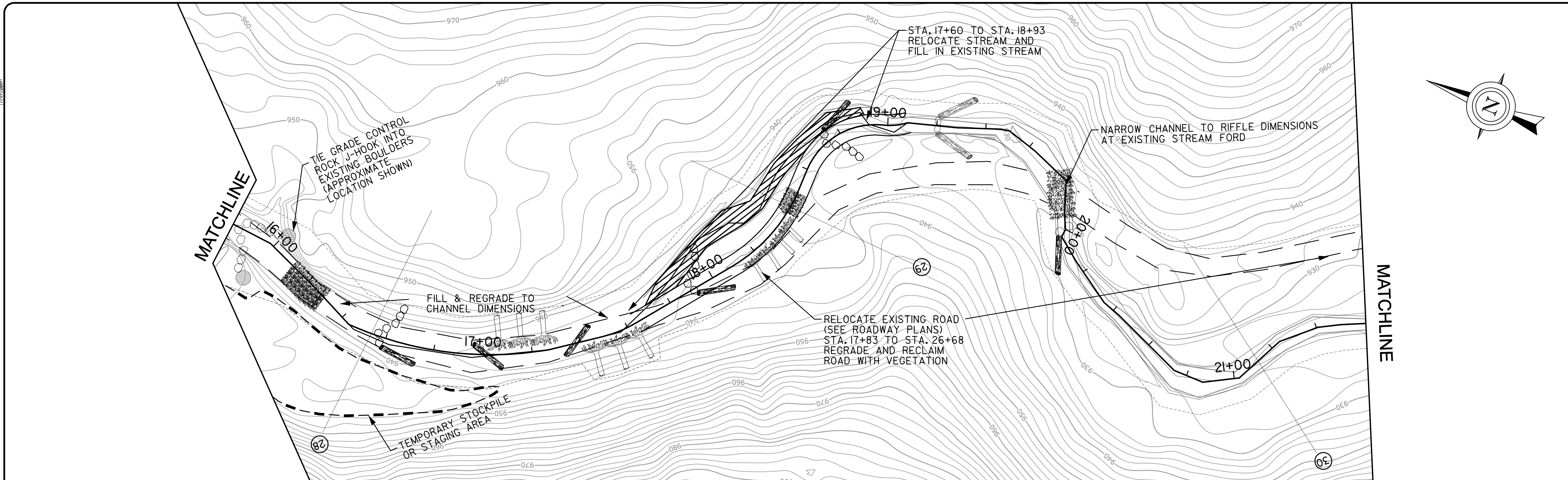

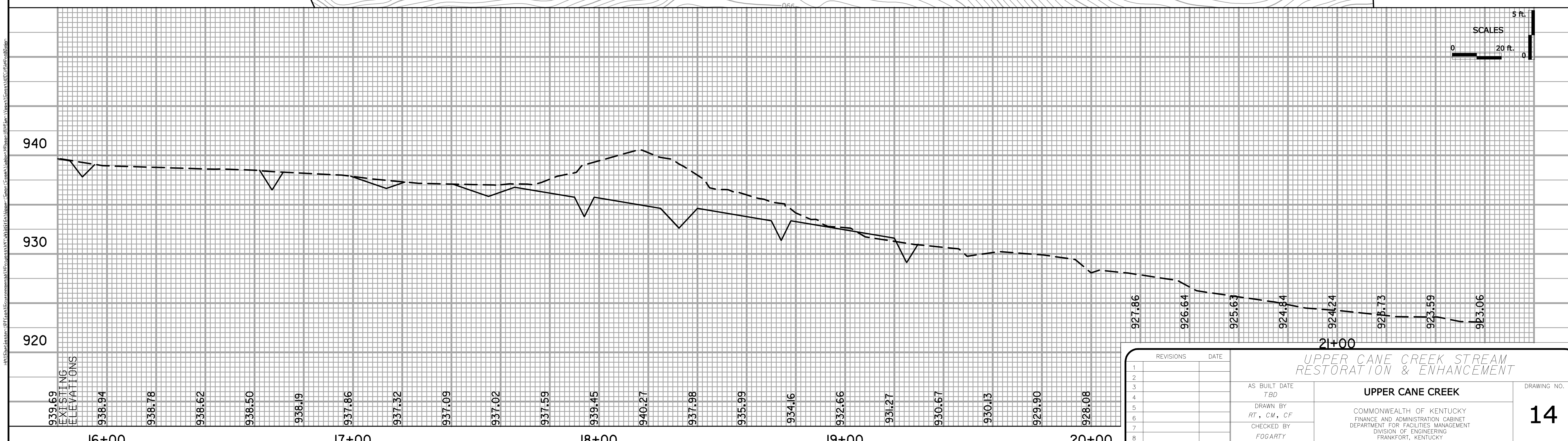

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MENIFEE COUNTY, KENTUCKY

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UPPER CANE CREEK STREAM
RESTORATION & ENHANCEMENT

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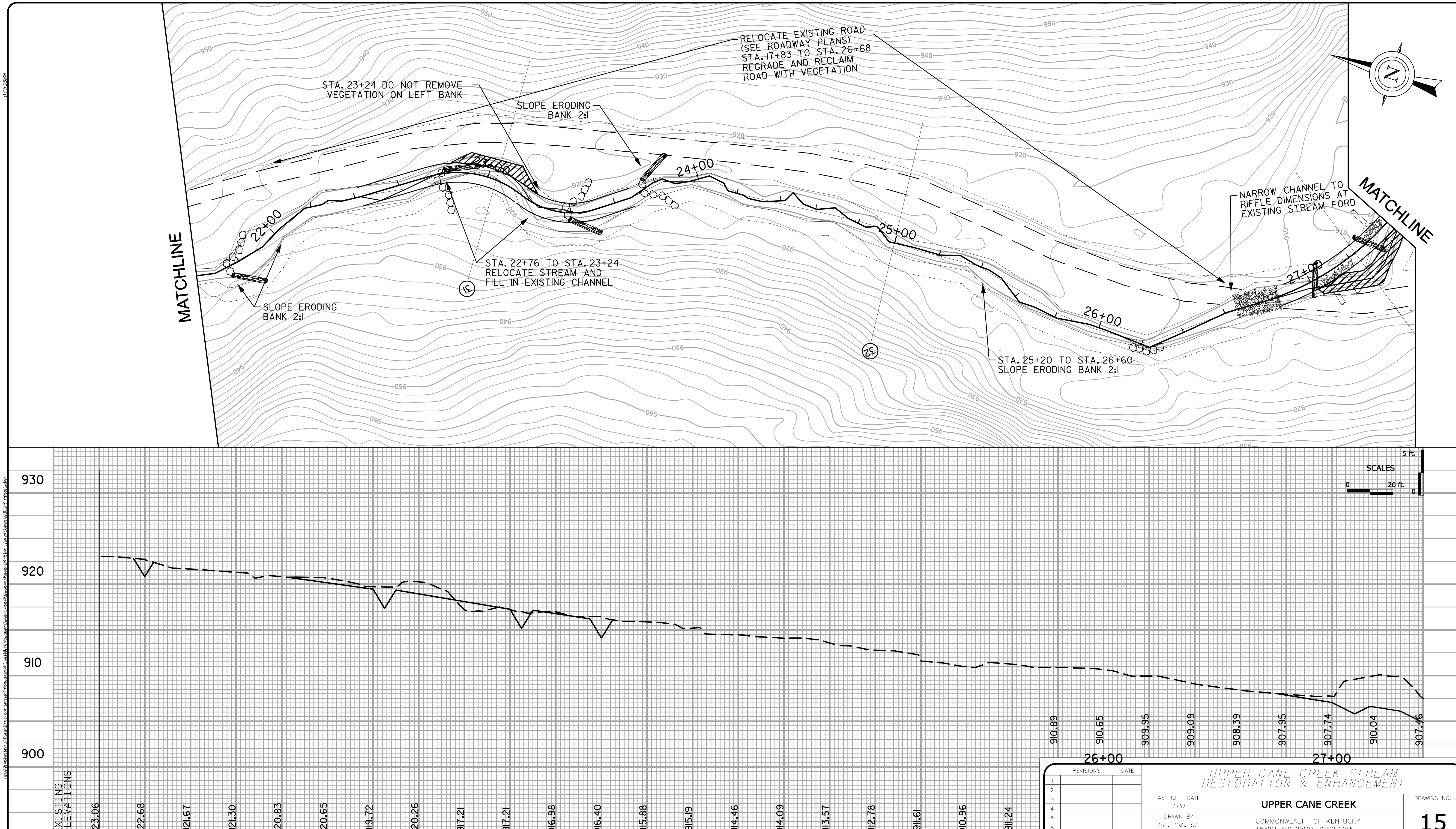

KENTUCKY FISH AND WILDLIFE
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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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UPPER CANE CREEK

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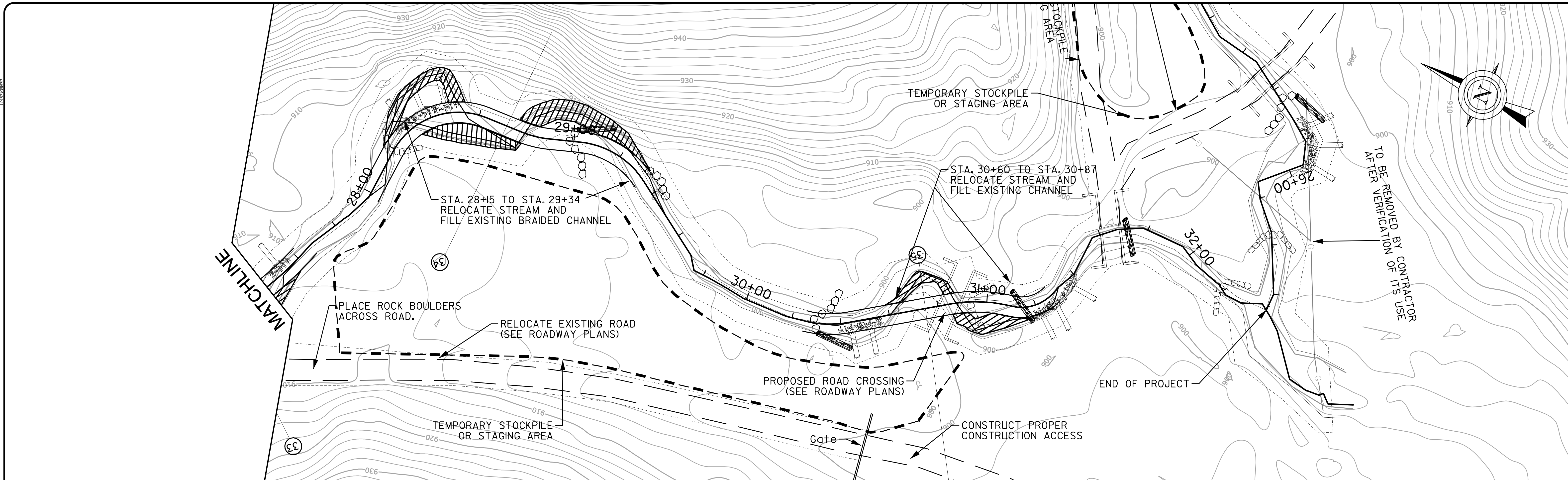

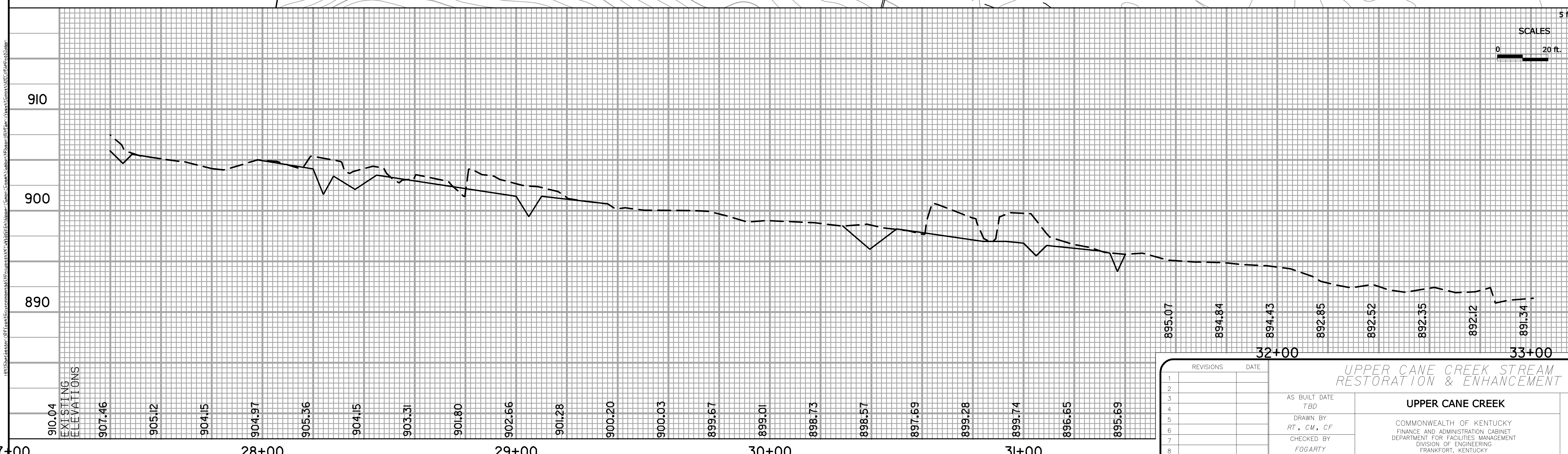

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UPPER CANE CREEK STREAM RESTORATION & ENHANCEMENT

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KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

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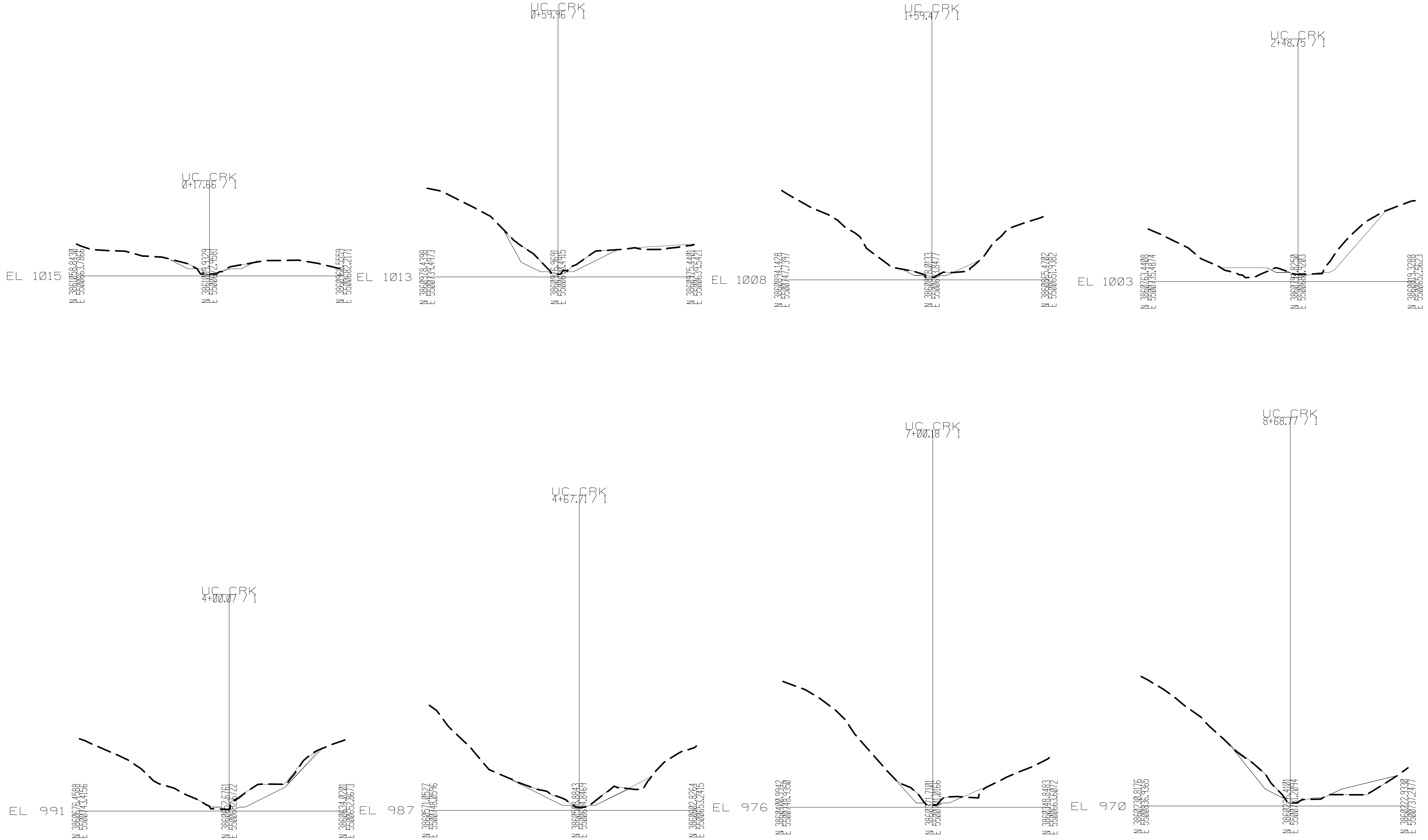

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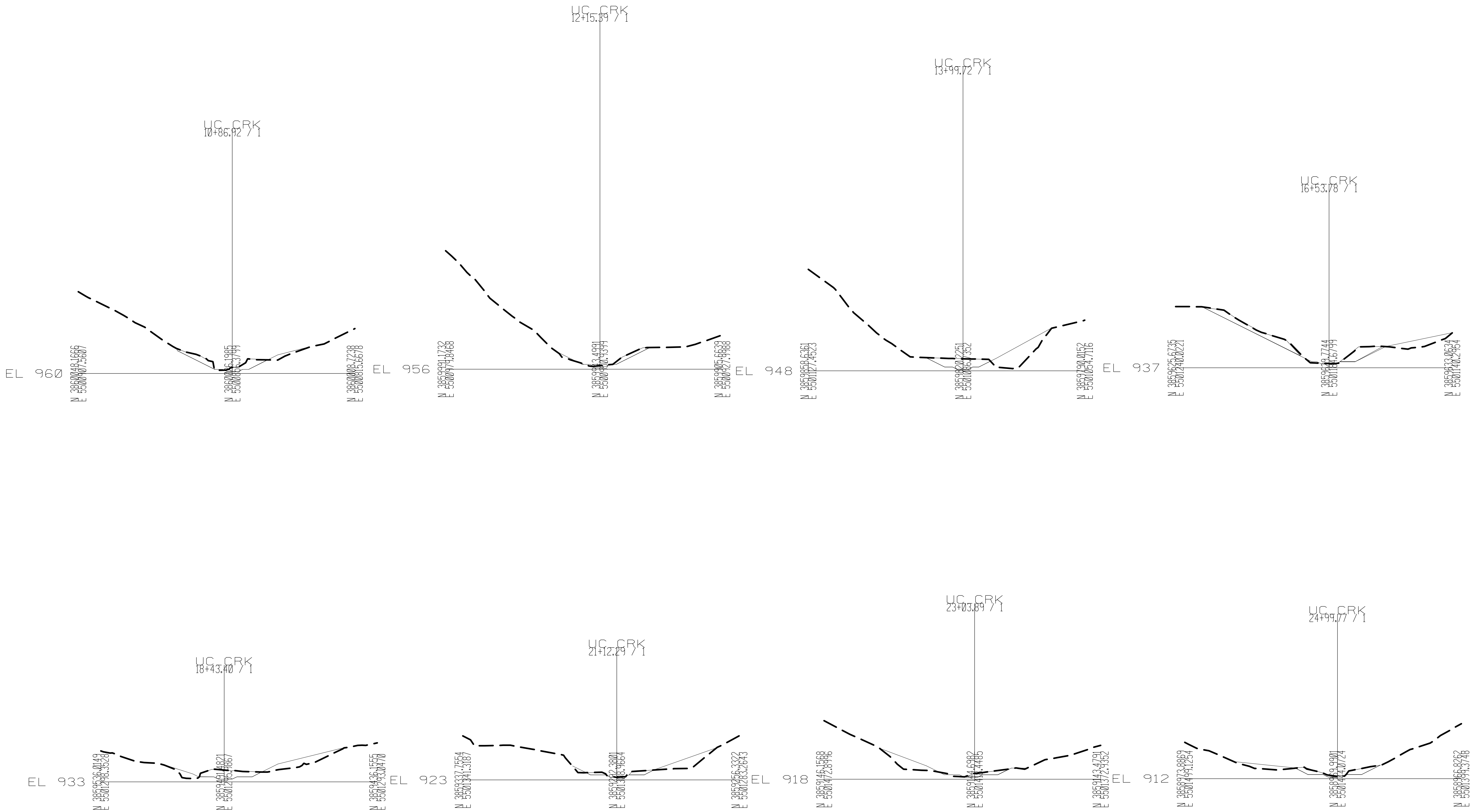

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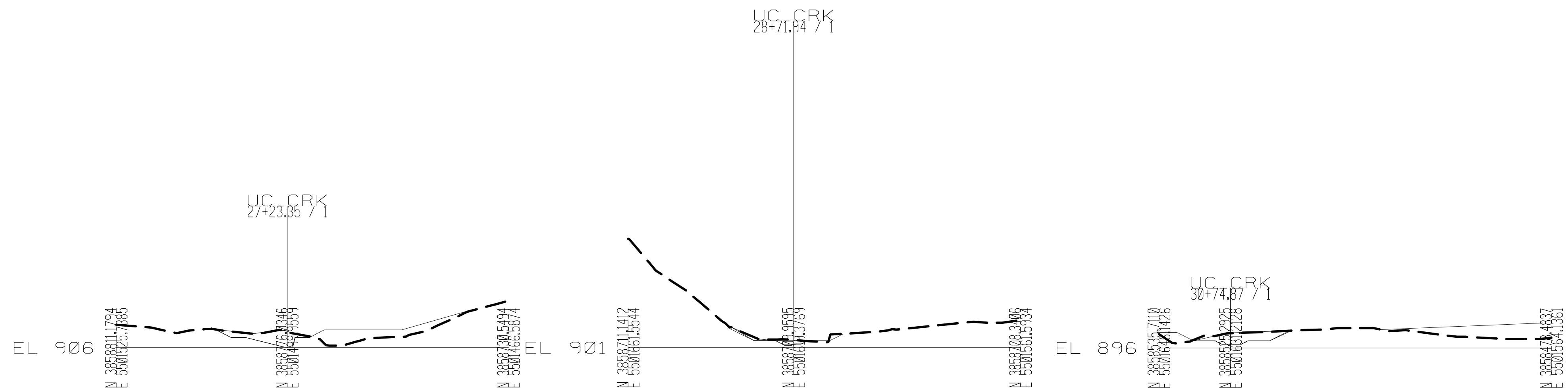

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UPPER CANE CREEK STREAM
RESTORATION & ENHANCEMENT

AS BUILT DATE: TBD
DRAWN BY: RT, CM, CF
CHECKED BY: FOGARTY
A&E FILE NO.: 110858
DATE: JAN. 19 2009

UPPER CANE CREEK

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

Baker
MICHAEL BAKER JR., INC.
5088 West Washington Street
Charleston, West Virginia 25313
(304)-769-0821 Office
(304)-769-0822 Fax

DRAWING NO. 19

REVIEWED
DIV. OF ENGR.
FOR INTENT ONLY
ACCOUNT NO. 660-CIKN-5402-00

SIGNATURE P.E.

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

DIVISION OF ENGINEERING — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

INDEX OF SHEETS

SHEET NO.	DESCRIPTION
R1	LAYOUT SHEET
R2	TYPICAL SECTIONS
R3	SUMMARY OF QUANTITIES
R4 - R6	PLAN SHEETS
R7 - R10	PROFILE SHEETS
X1 - X25	CROSS SECTION SHEETS

TOTAL SHEETS

(R) ROADWAY	10
(S) STRUCTURE	
(T) TRAFFIC	
(U) UTILITY	
(X) CROSS SECTION	25

STANDARD DRAWINGS

NUMBER

RDD-040-04

DESIGN CRITERIA

CLASS OF HIGHWAY	RURAL MINOR ACCESS ROAD
TYPE OF TERRAIN	MOUNTAINOUS
DESIGN SPEED	15 MPH RURAL
REQUIRED NPSD	65'
REQUIRED PSD	N/A
LEVEL OF SERVICE	N/A
ADT PRESENT ( )	LESS THAN 100
ADT FUTURE ( )	N/A
DHV	N/A
D %	N/A
T %	N/A

GEOGRAPHIC COORDINATES

LATITUDE ______ DEGREES ______ MINUTES NORTH

LONGITUDE ______ DEGREES ______ MINUTES WEST

DESIGNED

% RESTRICTED SD ______

LEVEL OF SERVICE ______

MAX.DISTANCE W/O PASSING ______

LENGTH 4870.57 LIN. FT. 0.922 MILES

ADDED / DEDUCTED FOR EQUALITIES ______ LIN. FT.

NOT INCLUDED

RAILROAD CROSSINGS NO. ______ LIN. FT.

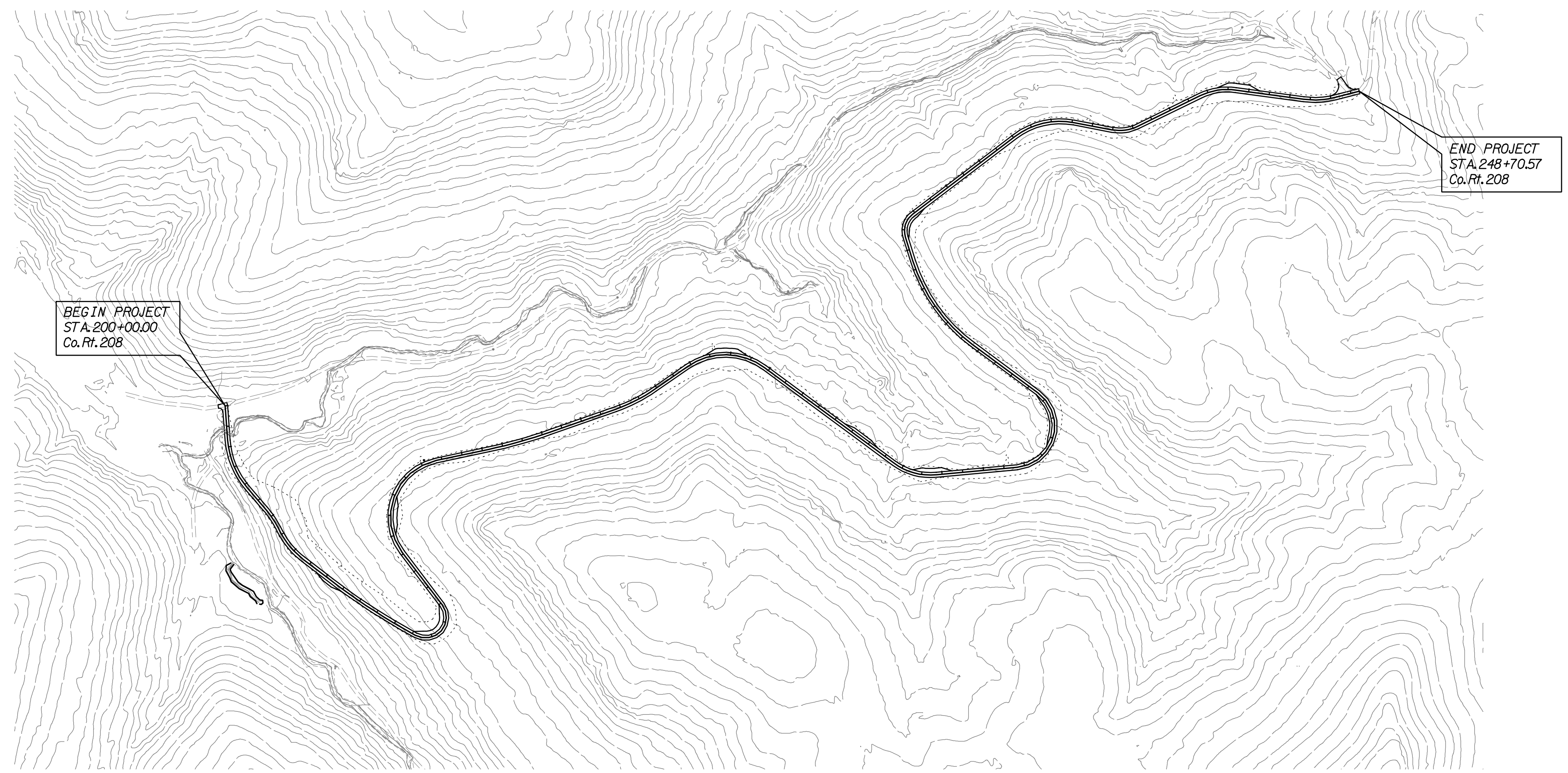
BRIDGES ______ LIN. FT.

COUNTY ROUTE 208 RELOCATION
MENIFEE COUNTY
UPPER CANE CREEK

KENTUCKY DEPARTMENT OF FISH & WILDLIFE RESOURCES
#1 SPORTSMAN'S LANE
FRANKFORT, KY 40601
Account # 660-C1KN-5402-00

COMMONWEALTH OF KENTUCKY
GOVERNOR STEVE BESHEAR

FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING AND CONTRACT ADMINISTRATION



SCALE : 0 200 FT.

LAYOUT MAP

NO.	DATE	BY	REVISION

PRELIMINARY PLANS
DO NOT USE FOR CONSTRUCTION
01/19/09

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker
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5088 West Washington Street
Charleston, West Virginia 25313
Phone 304-769-0821
Fax 304-769-0822

LETTING DATE:

P. Fogarty
PROJECT ENGINEER

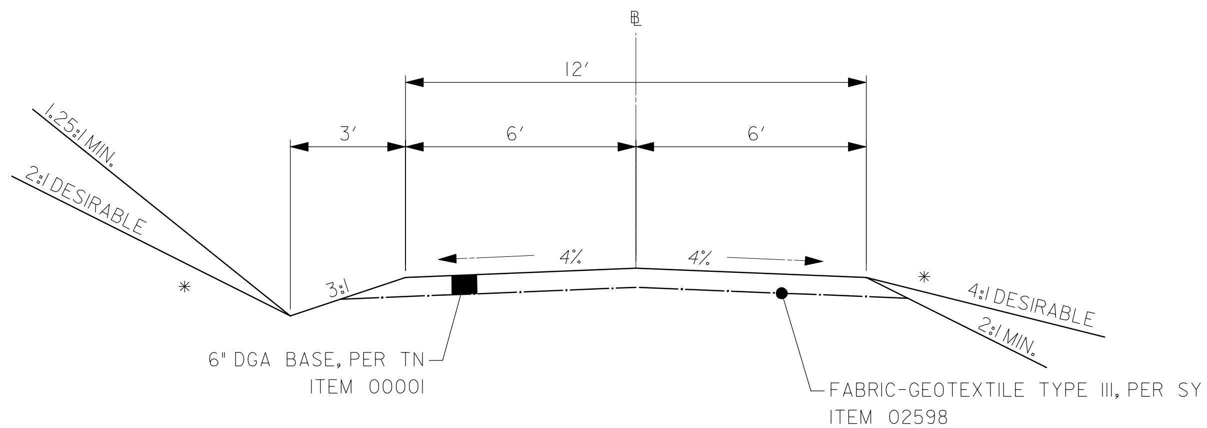
C. Mower / A. Rogers
PROJECT DESIGNER

PROJECT ENGINEER

P.E.

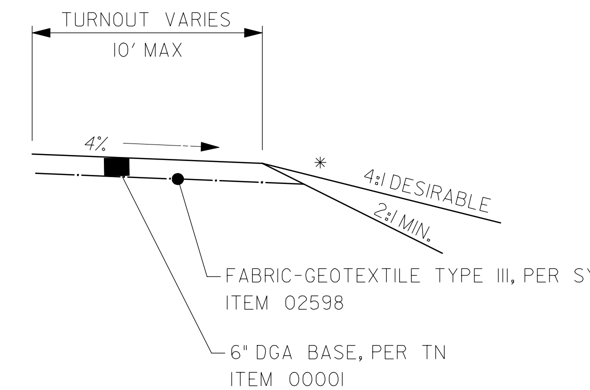
SIGNATURE:

SHEET
R1

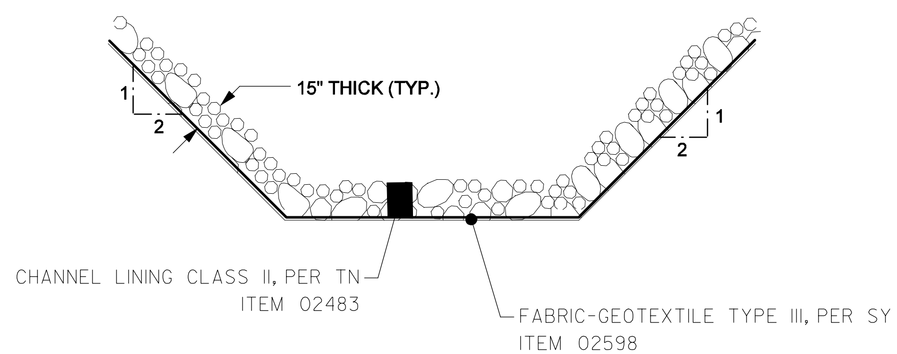


COUNTY ROUTE 208
NORMAL SECTION
STA. 200+00 TO STA. 248+70.57

* - SLOPE VARIES SEE CROSS SECTIONS



COUNTY ROUTE 208
TURNOUT SECTION
SEE PLAN FOR LOCATIONS



COUNTY ROUTE 208
FORD STREAM CROSSING
SEE PLAN FOR LOCATIONS

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker
Michael Baker Jr., Inc.
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Fax 304-769-0822

REVISIONS	DATE
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UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

AS BUILT DATE TBD
DRAWN BY RH, TB
CHECKED BY FOGARTY
A&E FILE NO. 110858
DATE OCT. 21 2008

TYPICACL SECTIONS

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

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DRAWING NO. R2
REVIEWED DIV. OF ENGR.
FOR INTENT ONLY
ACCOUNT NO. 660-CIKN-5402-00

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE
DIVISION OF ENGINEERING — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

GENERAL SUMMARY

ITEM	DESCRIPTION	UNIT	CO.RT. 208			PROJECT TOTALS
2200	ROADWAY EXCAVATION	CY	16,058			16,058
2483	CHANNEL LINING CLASS II (3)	TN	538			538
2545	CLEARING AND GRUBBING (2)	LS	1			1
2679	POROUS UNDERDRAIN	LF	201			201
5950	EROSION CONTROL BLANKET	SY	1445			1445
5953	TEMP SEEDING AND PROTECTION	SY	6051			6051
5985	SEEDING AND PROTECTION	SY	12,101			12,101
8019	CYCLOPEAN STONE RIPRAP (3)	TN	35			35

PAVING AREAS

ITEM	CO.RT. 208	CO. RT. 208 CONNECTION	TURNOUTS	FORD STREAM CROSSINGS	DRIVEWAY ENTRANCE	TOTAL PROJECT
	SQUARE YARDS					
4" DENSE GRADED AGGREGATE	6376	21	654		93	7144
15" CHANNEL LINING CLASS II				184		184
FABRIC - GEOTEXTILE TYPE III	6376	21	654	184	93	7328

PAVING SUMMARY

ITEM CODE	ITEM	UNIT	CO.RT. 208	CO. RT. 208 CONNECTION	TURNOUTS	FORD STREAM CROSSINGS	DRIVEWAY ENTRANCE	TOTAL PROJECT
1	DENSE GRADED AGGREGATE (1)	TN	2200	8	226		33	2467
2483	CHANNEL LINING CLASS II (3)	TN				115		115
2598	FABRIC - GEOTEXTILE TYPE III	SY	6376	21	654	184	93	7328

NOTES

1. ESTIMATED AT 115 LBS.PER SQ. YD.PER INCH OF DEPTH.
2. APPROXIMATELY 3.6 ACRES.
3. ESTIMATED AT 0.5 TN PER SQ. YD.PER FOOT OF DEPTH.

TOTAL ROADWAY EXCAVATION = 16,058 C.Y.
TOTAL ROADWAY EMBANKMENT = 1,276 C.Y.

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

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REVISIONS	DATE
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SIGNATURE P.E.

UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

AS BUILT DATE TBD
DRAWN BY RH, TB
CHECKED BY FOGARTY
A&E FILE NO. 110858
DATE OCT. 21 2008

GENERAL SUMMARY

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

Baker MICHAEL BAKER JR., INC.
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DRAWING NO. R3

REVIEWED DIV. OF ENGR.
FOR INTENT ONLY
ACCOUNT NO. 660-CIKN-5402-00

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE
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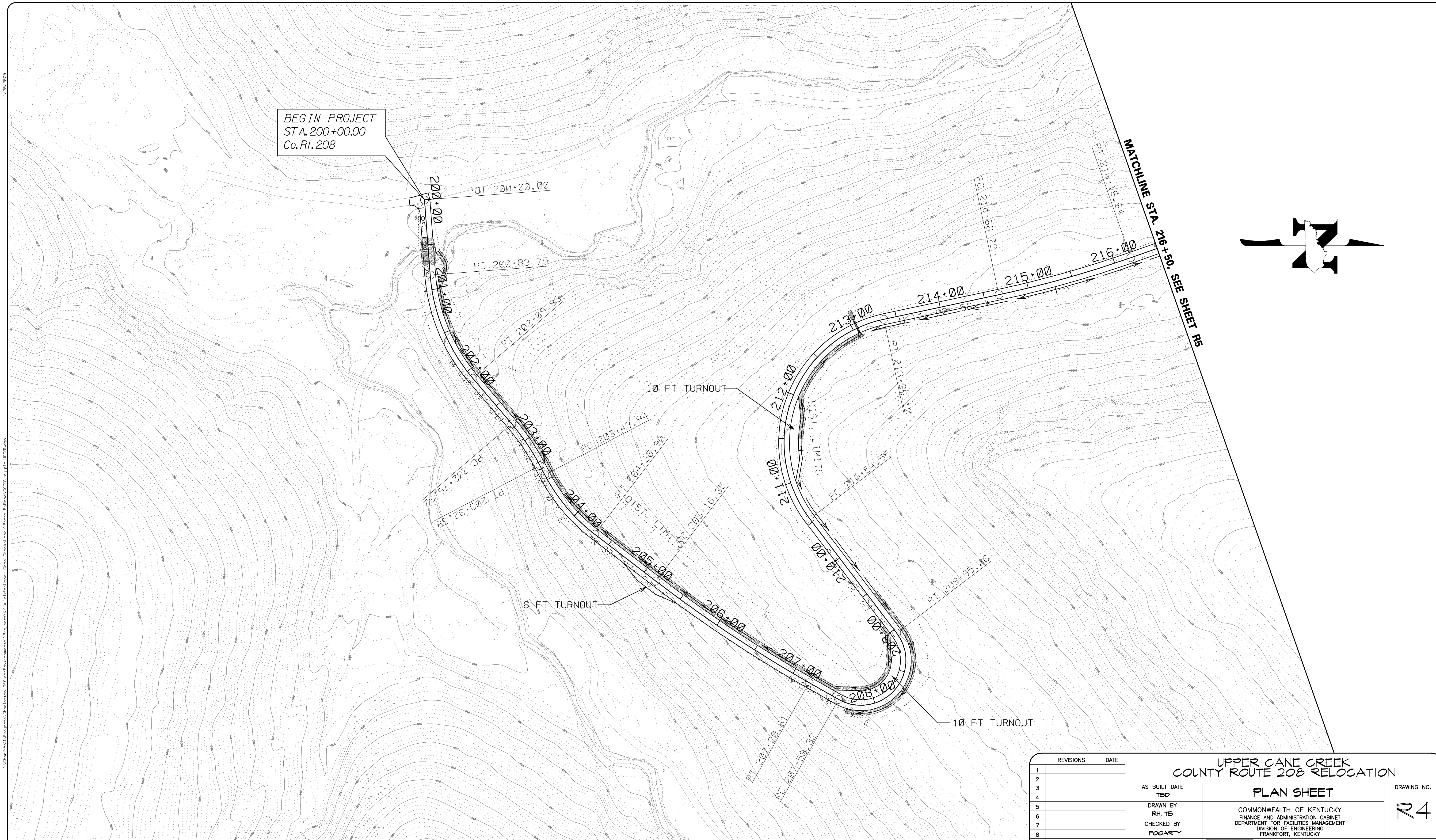

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker
Michael Baker Jr., Inc.
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Charleston, West Virginia 25313
Phone 304-769-0821
Fax 304-769-0822

SCALE : 0 50 FT.

REVISIONS	DATE
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SIGNATURE P.E.

UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

PLAN SHEET

AS BUILT DATE: TBD
DRAWN BY: RH, TB
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A&E FILE NO.: 110858
DATE: OCT. 21 2008

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

Baker
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DRAWING NO.
R4

REVIEWED DIV. OF ENGR.
FOR INTENT ONLY
ACCOUNT NO.
660-CIKN-5402-00

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

DIVISION OF ENGINEERING — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

	REVISIONS	DATE
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UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

PLAN SHEET

AS BUILT DATE: TBD
DRAWN BY: RH, TB
CHECKED BY: FOGARTY
A&E FILE NO.: 110858
DATE: OCT. 21 2008

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

DRAWING NO. R5

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(304)-769-0822 Fax

REVIEWED DIV. OF ENGR.
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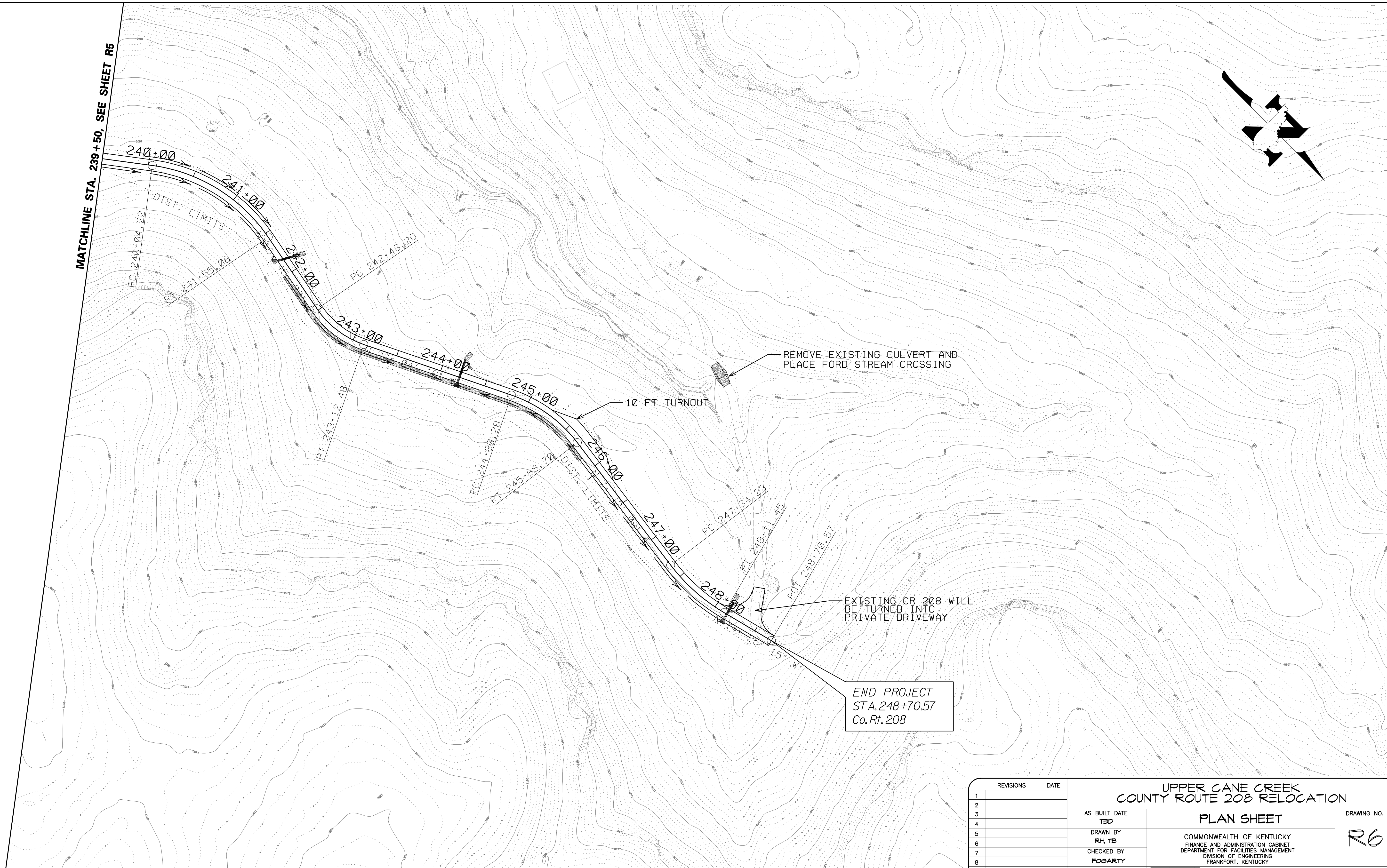
KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker
Michael Baker Jr., Inc.
5088 West Washington Street
Charleston, West Virginia 25313
Phone 304-769-0821
Fax 304-769-0822

SCALE : 0 50 FT.



KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

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Fax 304-769-0822

SCALE : 0 50 FT.

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SIGNATURE P.E.

UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

PLAN SHEET

AS BUILT DATE: TBD
DRAWN BY: RH, TB
CHECKED BY: FOGARTY
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DATE: OCT. 21 2008

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

DRAWING NO. R6

Baker
MICHAEL BAKER JR., INC.
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Charleston, West Virginia 25313
(304)-769-0821 Office
(304)-769-0822 Fax

REVIEWED
DIV. OF ENGR.
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660-CIKN-5402-00

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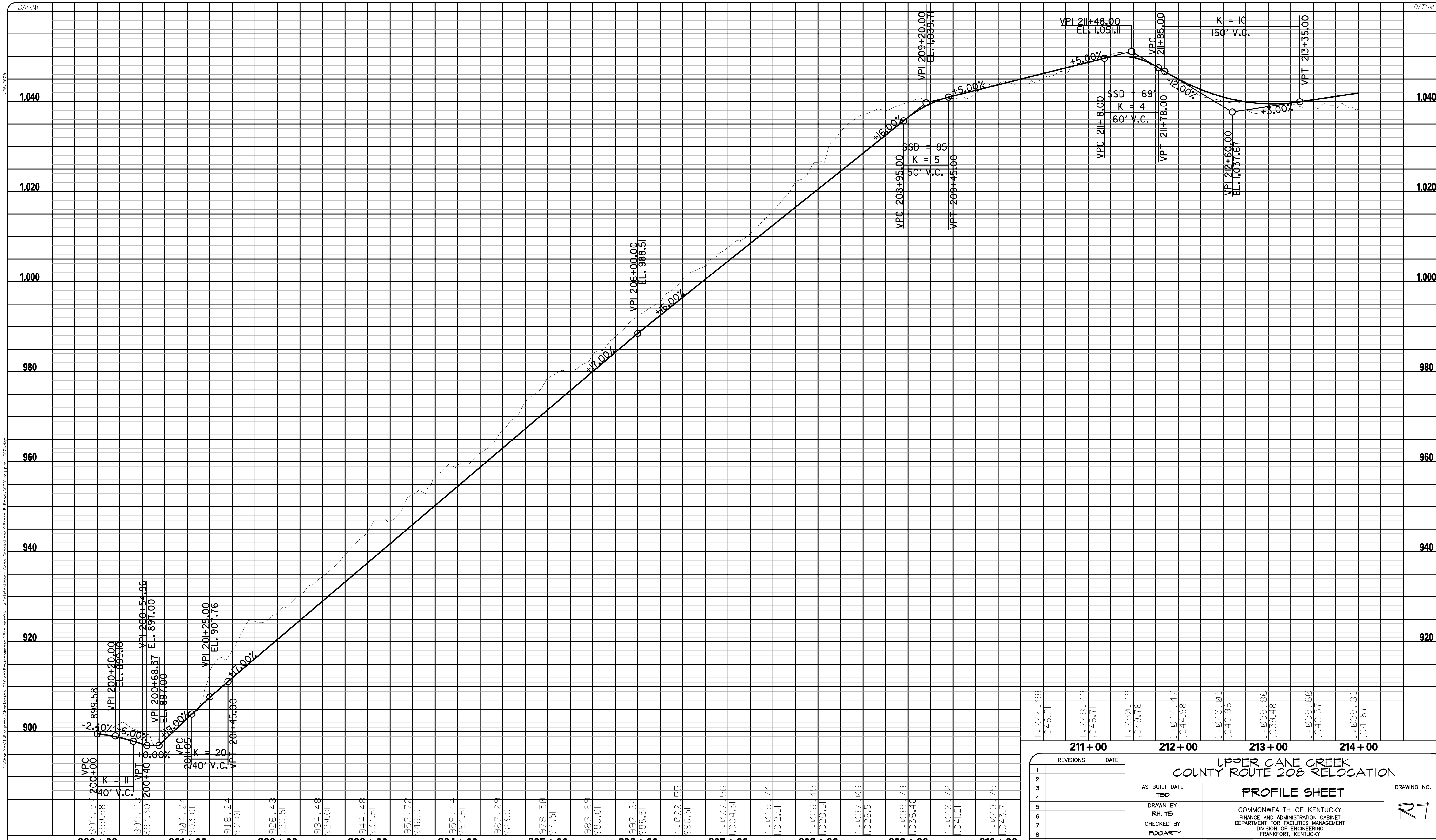

UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

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AS BUILT DATE: TBD

DRAWN BY: RH, TB

CHECKED BY: FOGARTY

A&E FILE NO.: 110858

DATE: OCT. 21 2008

PROFILE SHEET

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

DRAWING NO. R7

Baker
MICHAEL BAKER JR., INC.
5088 West Washington Street
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REVIEWED DIV. OF ENGR.
FOR INTENT ONLY
ACCOUNT NO. 660-CIKN-5402-00

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

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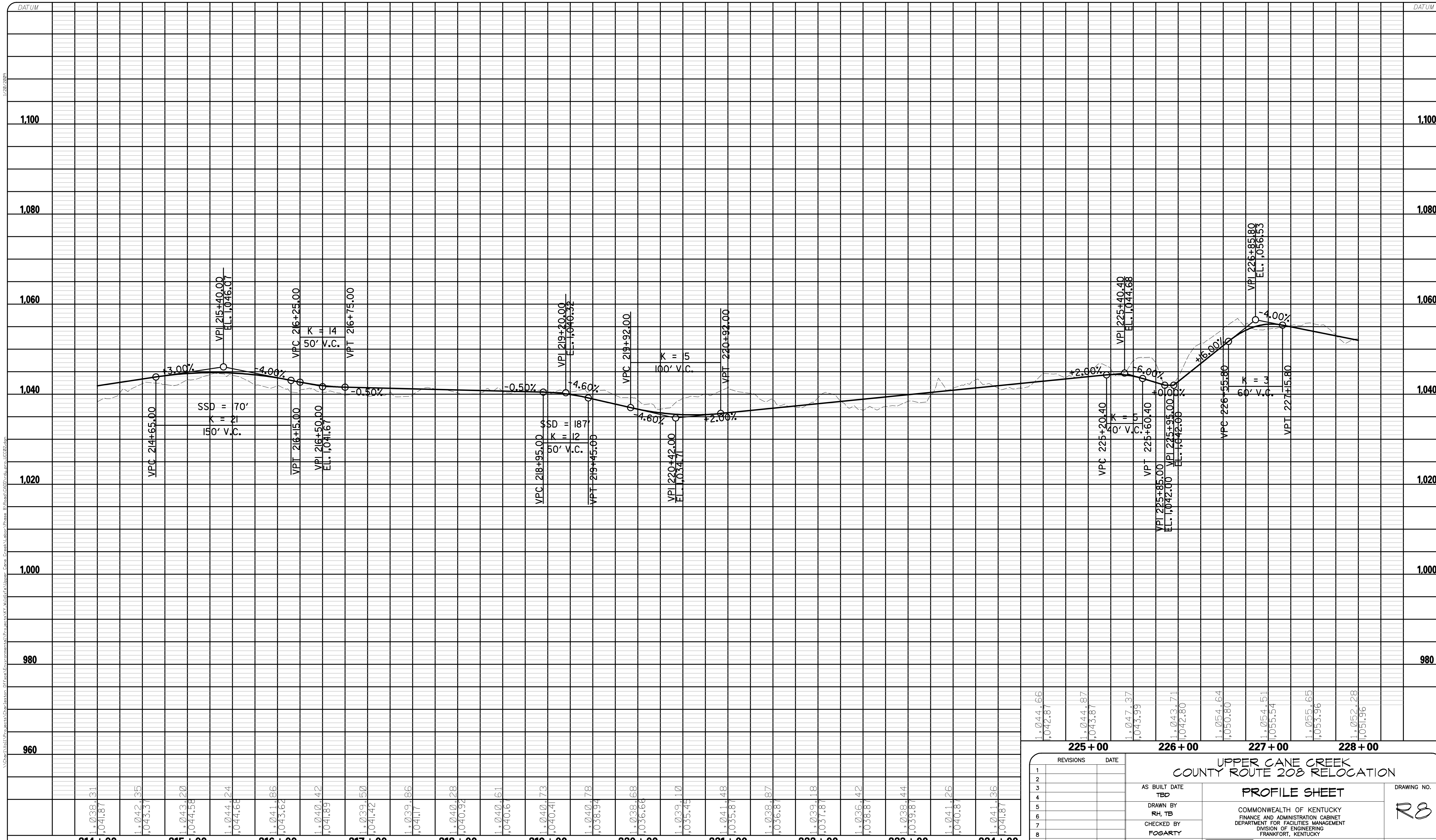
SIGNATURE P.E.

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker
Michael Baker Jr., Inc.
5088 West Washington Street
Charleston, West Virginia 25313
Phone 304-769-0821
Fax 304-769-0822

SCALES
10 FT.
0 50 FT. 0



KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker

Michael Baker Jr., Inc.
5088 West Washington Street
Charleston, West Virginia 25313

Phone 304-769-0821
Fax 304-769-0822

SCALES
10 FT.
0 50 FT. 0

REVISIONS	DATE
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UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

AS BUILT DATE: TBD

PROFILE SHEET

DRAWING NO.: R8

DRAWN BY: RH, TB

CHECKED BY: FOGARTY

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

A&E FILE NO.: 110858

DATE: OCT. 21 2008

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REVIEWED DIV. OF ENGR.

FOR INTENT ONLY

ACCOUNT NO.: 660-CIKN-5402-00

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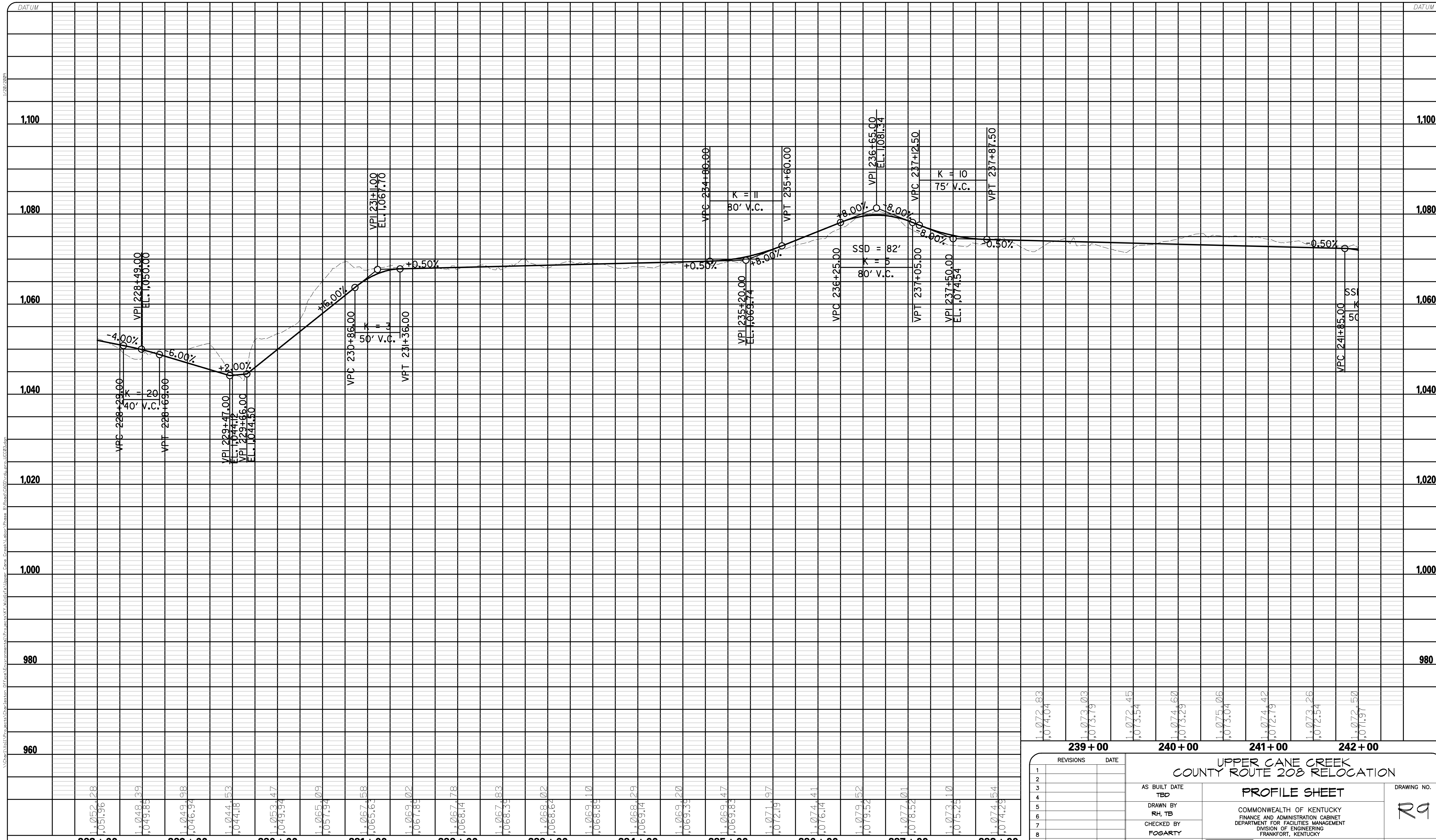

KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker

Michael Baker Jr., Inc.
5088 West Washington Street
Charleston, West Virginia 25313

Phone 304-769-0821
Fax 304-769-0822

SCALES
10 FT.
0 50 FT. 0

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SIGNATURE P.E.

UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

PROFILE SHEET

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CHECKED BY: FOGARTY
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DATE: OCT. 21 2008

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

DRAWING NO. R9

Baker
MICHAEL BAKER JR., INC.
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Charleston, West Virginia 25313
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(304)-769-0822 Fax

REVIEWED DIV. OF ENGR.
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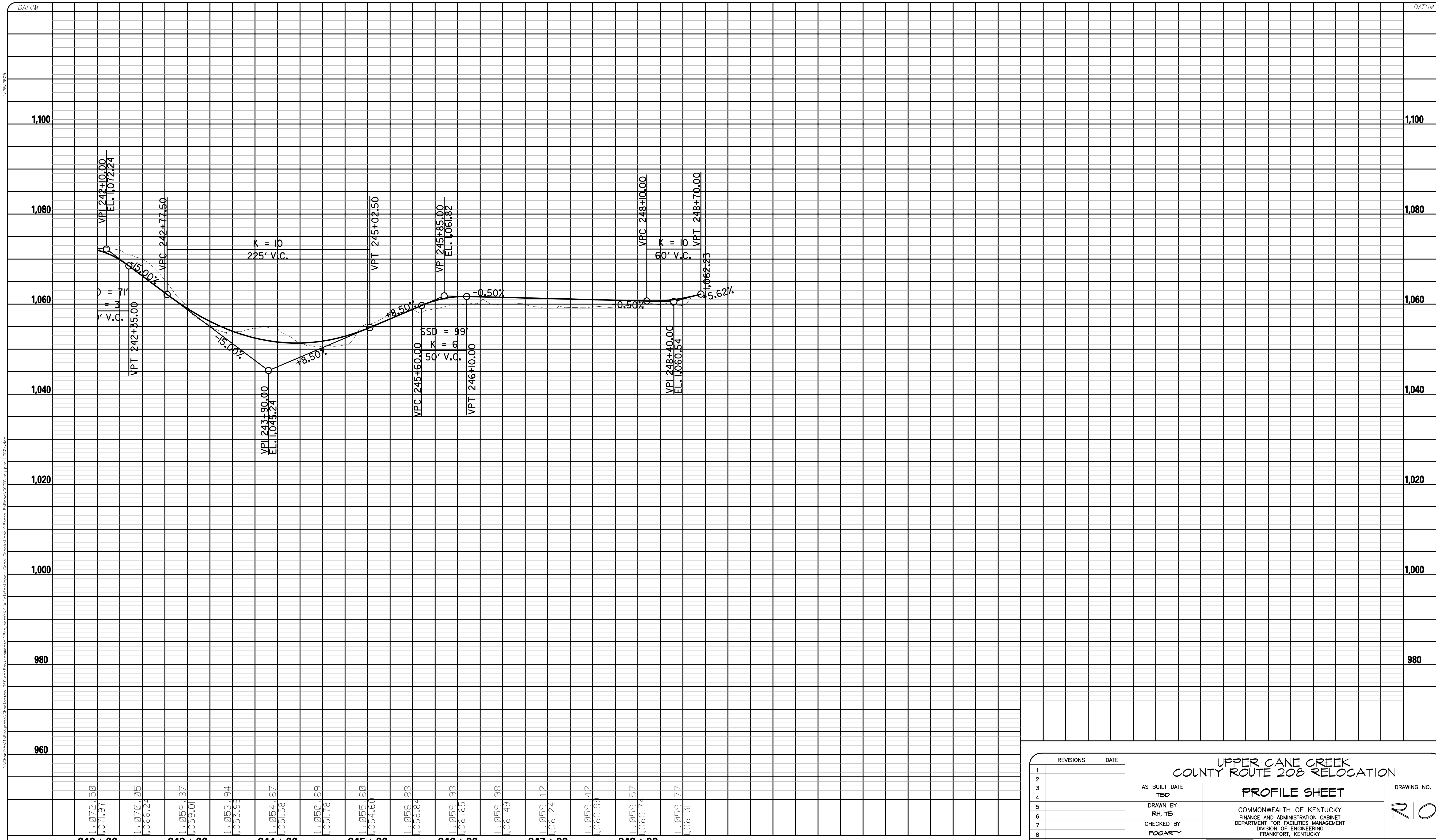
ACCOUNT NO. 660-CIKN-5402-00

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

DIVISION OF ENGINEERING — APPROVED FOR PROGRAM CONCEPT ONLY — DATE



KENTUCKY FISH AND WILDLIFE
MENIFEE COUNTY, KENTUCKY

Baker

Michael Baker Jr., Inc.
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Charleston, West Virginia 25313
Phone 304-769-0821
Fax 304-769-0822

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SCALES
0 50 FT. 0

REVISIONS	DATE
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SIGNATURE P.E.

UPPER CANE CREEK
COUNTY ROUTE 208 RELOCATION

PROFILE SHEET

AS BUILT DATE: TBD
DRAWN BY: RH, TB
CHECKED BY: FOGARTY
A&E FILE NO.: 110858
DATE: OCT. 21 2008

COMMONWEALTH OF KENTUCKY
FINANCE AND ADMINISTRATION CABINET
DEPARTMENT FOR FACILITIES MANAGEMENT
DIVISION OF ENGINEERING
FRANKFORT, KENTUCKY

DRAWING NO. R10

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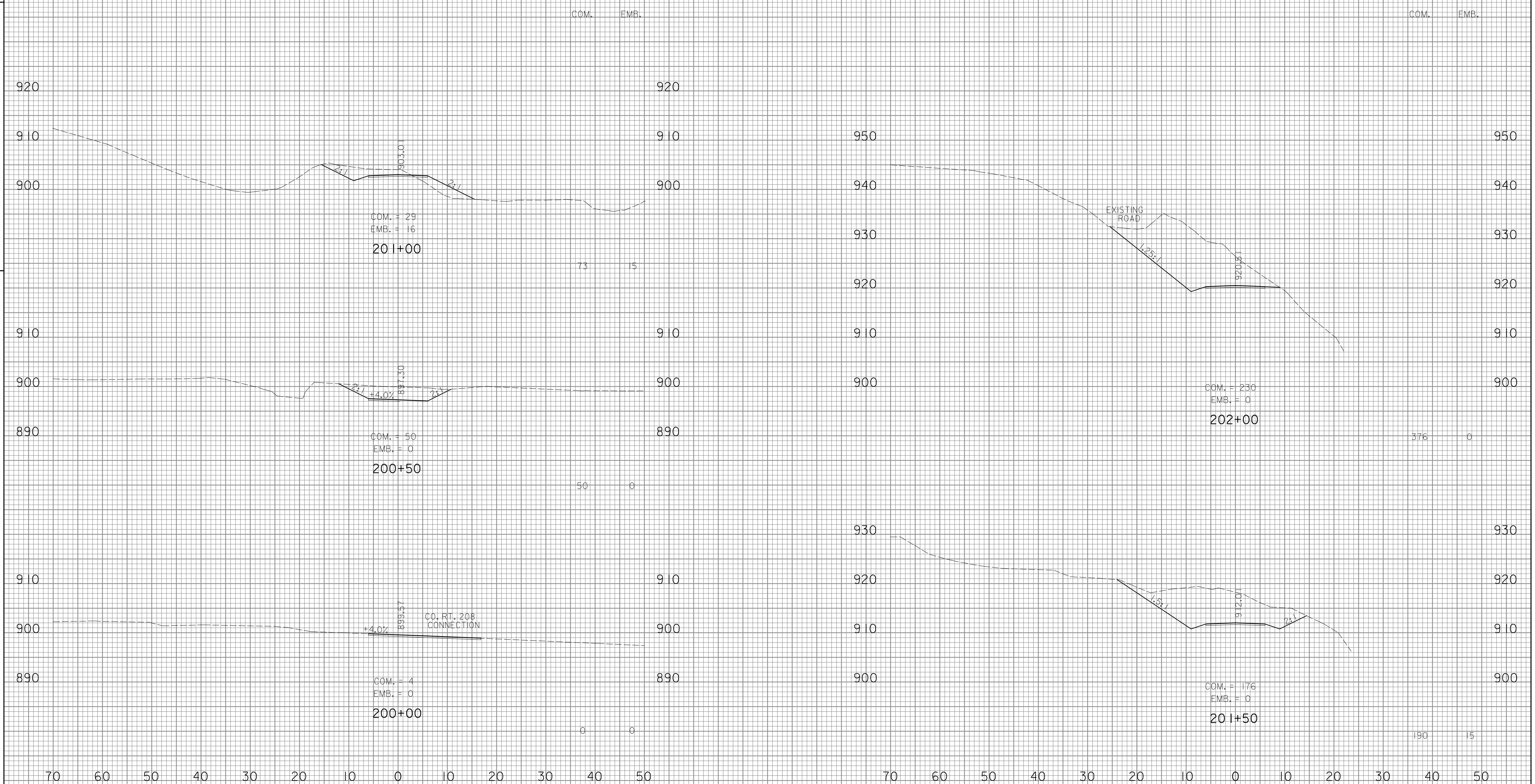
ACCOUNT NO. 660-CIKN-5402-00

AGENCY AUTHORIZED AGENT — APPROVED FOR PROGRAM CONCEPT ONLY — DATE
DIVISION OF ENGINEERING — APPROVED FOR PROGRAM CONCEPT ONLY — DATE

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X1

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______



MENIFEE

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

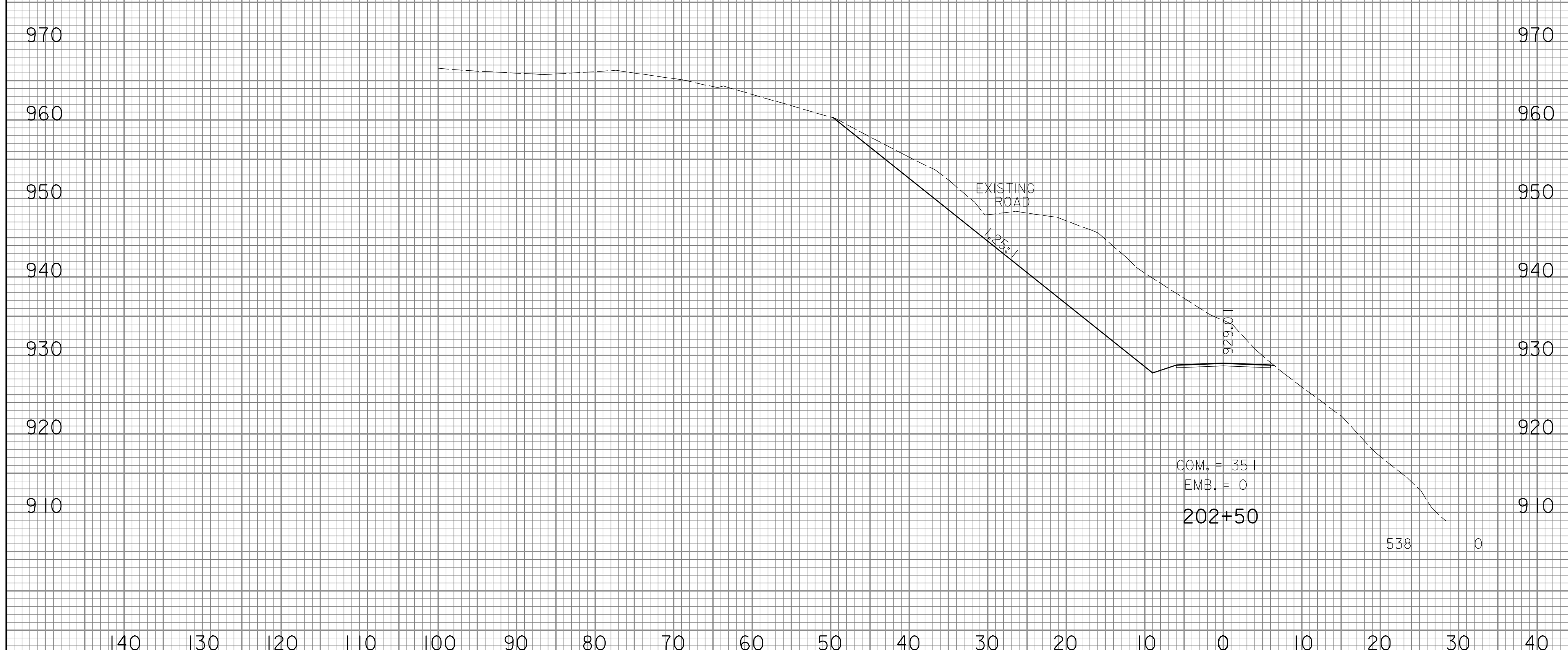
COUNTY ROUTE 208
STA.200+00 TO STA.202+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X2

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

COM. EMB.



SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208
STA.202+50 TO STA.202+50

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X3

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

COM. EMB.

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.203+00 TO STA.203+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X4

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

COM. EMB.

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.203+50 TO STA.203+50

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X5

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

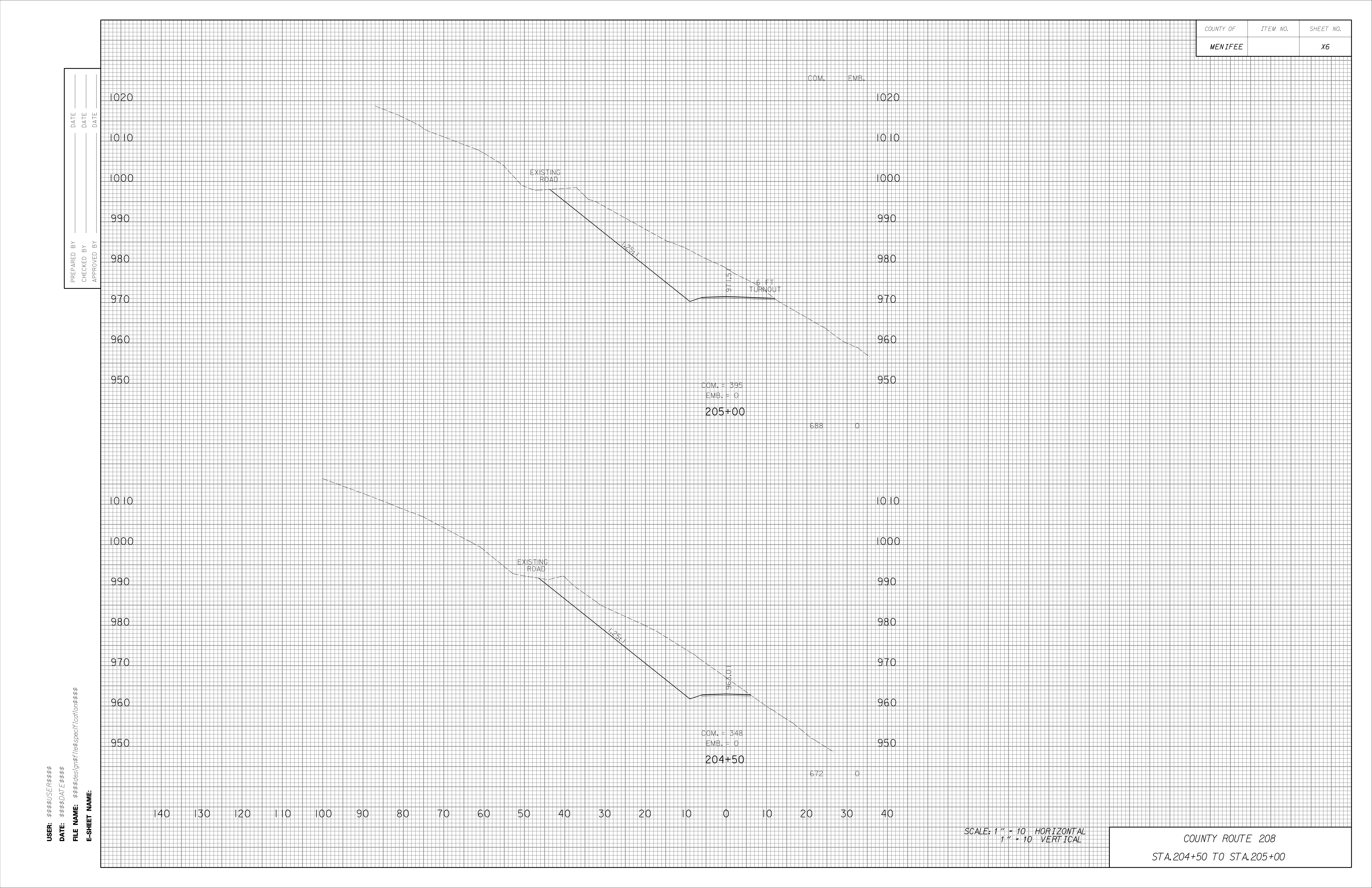
COM. EMB.

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.204+00 TO STA.204+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:



COUNTY OF
ITEM NO.
SHEET NO.
MENIFEE
X6
PREPARED BY
DATE
CHECKED BY
DATE
APPROVED BY
DATE
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EMB.
1020
1010
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990
980
970
960
950
EXISTING ROAD
1.25:1
971.5
6 FT. TURNOUT
COM. = 395
EMB. = 0
205+00
688
0
1010
1000
990
980
970
960
950
EXISTING ROAD
1.25:1
962.0
COM. = 348
EMB. = 0
204+50
672
0
140
130
120
110
100
90
80
70
60
50
40
30
20
10
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10
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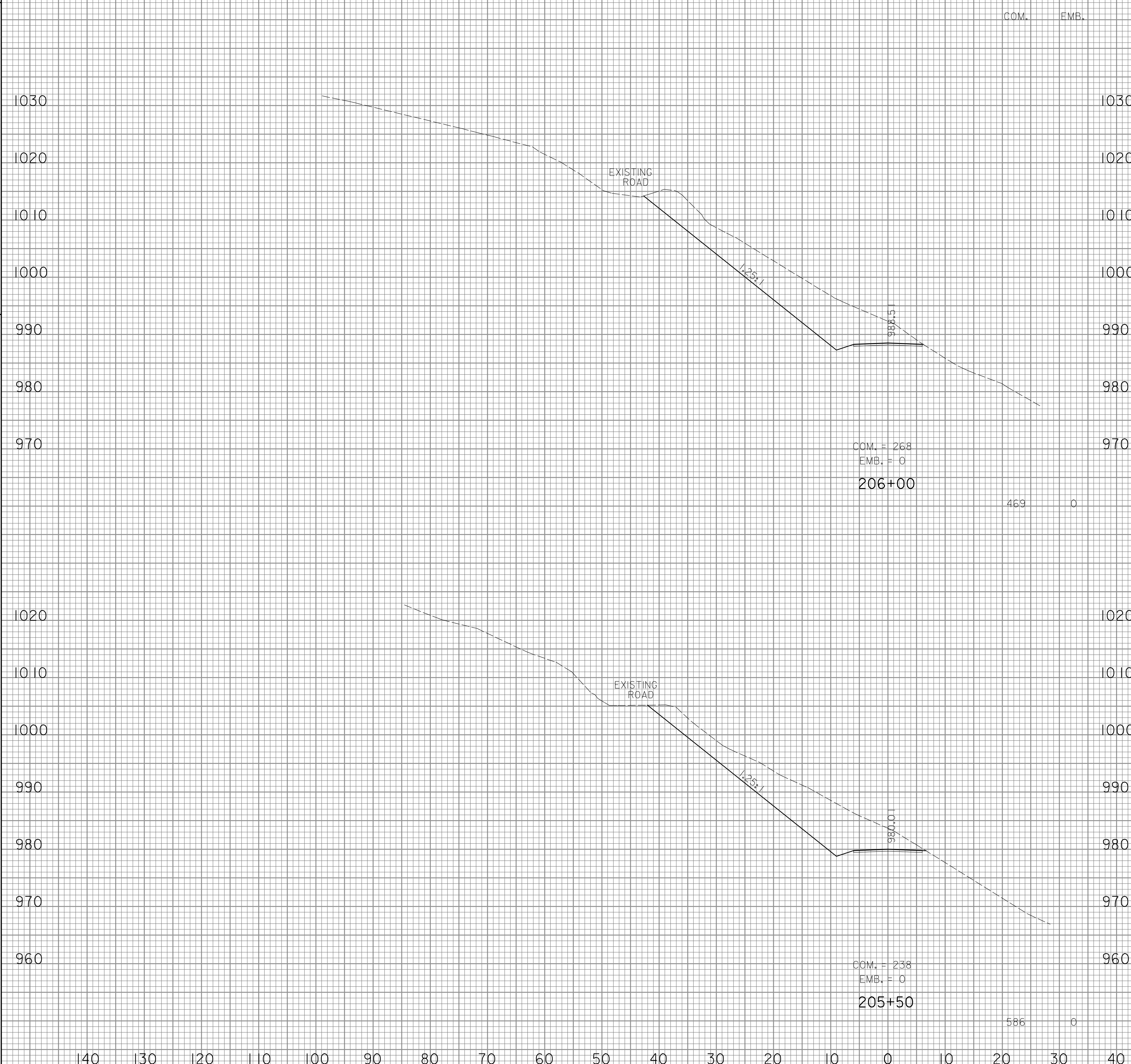
30
40
SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL
COUNTY ROUTE 208
STA.204+50 TO STA.205+00
USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X7

PREPARED BY ____ DATE ____
CHECKED BY ____ DATE ____
APPROVED BY ____ DATE ____



SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

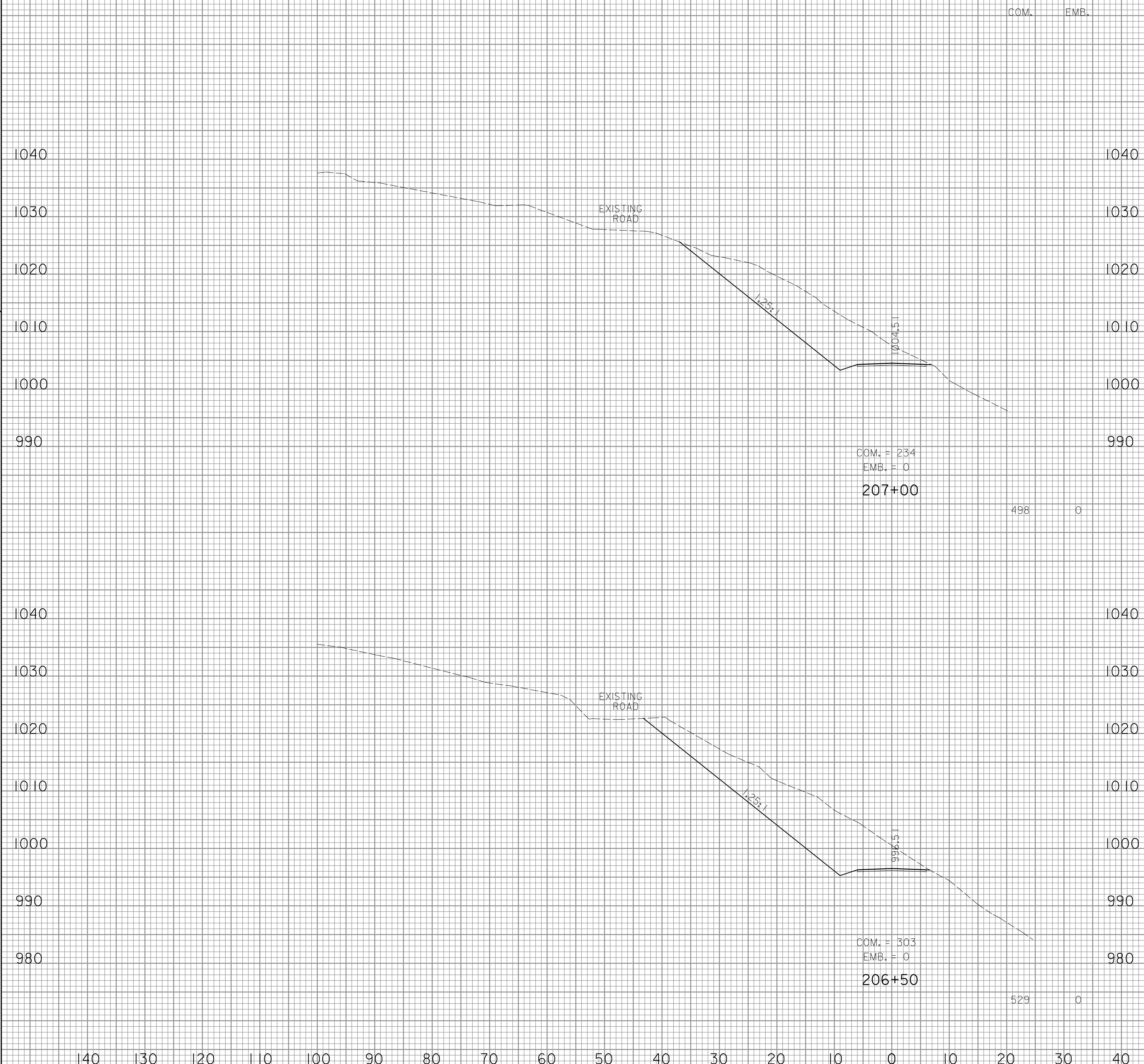
COUNTY ROUTE 208

STA.205+50 TO STA.206+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X8

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______



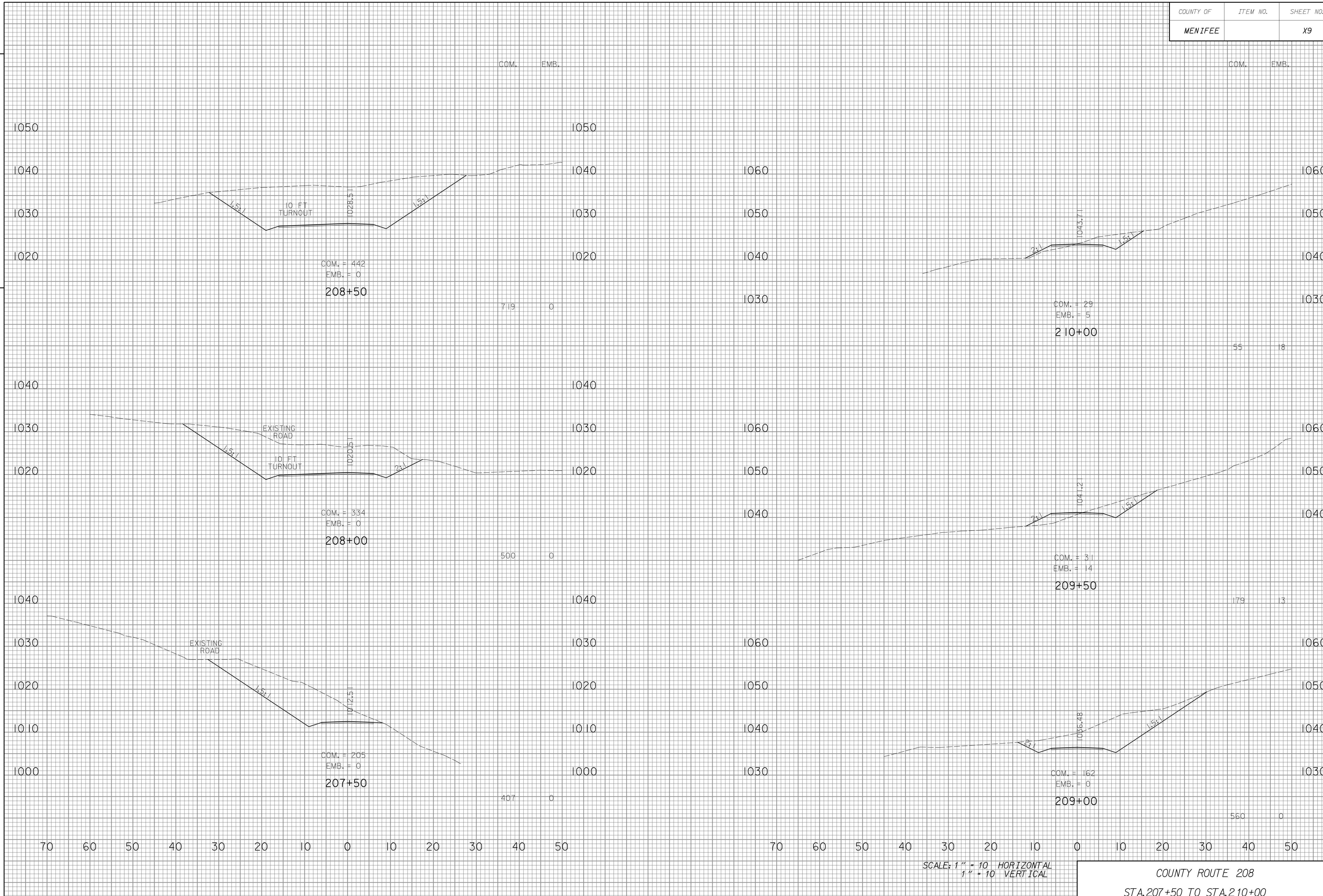
SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.206+50 TO STA.207+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______



USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

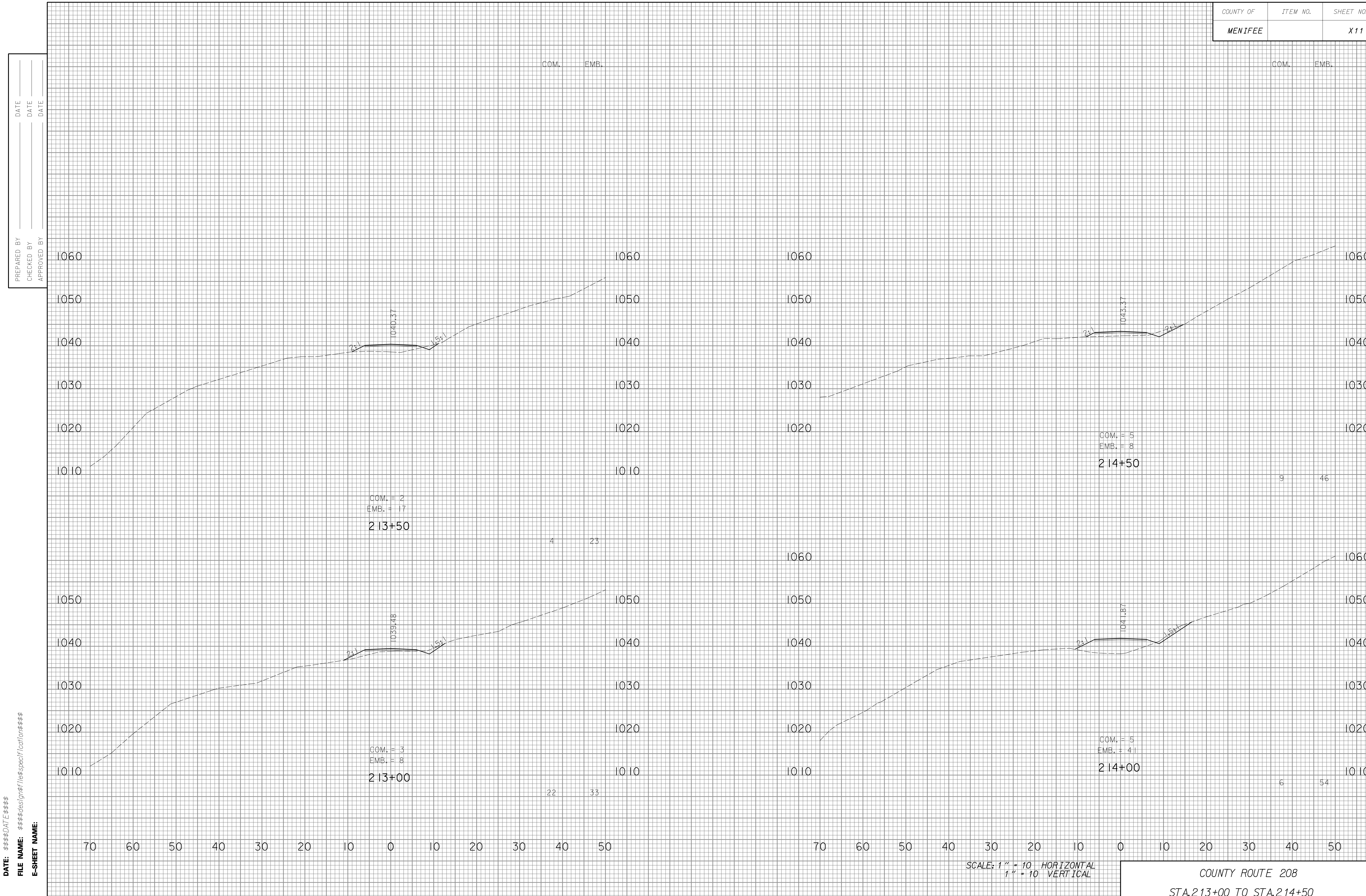
COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X10

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208
STA.210+50 TO STA.212+50

PREPARED BY ____ DATE ____
CHECKED BY ____ DATE ____
APPROVED BY ____ DATE ____

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:



USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X12

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208
STA.215+00 TO STA.217+00

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X13

PREPARED BY ________ DATE ________
CHECKED BY ________ DATE ________
APPROVED BY ________ DATE ________

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.217+50 TO STA.219+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X14

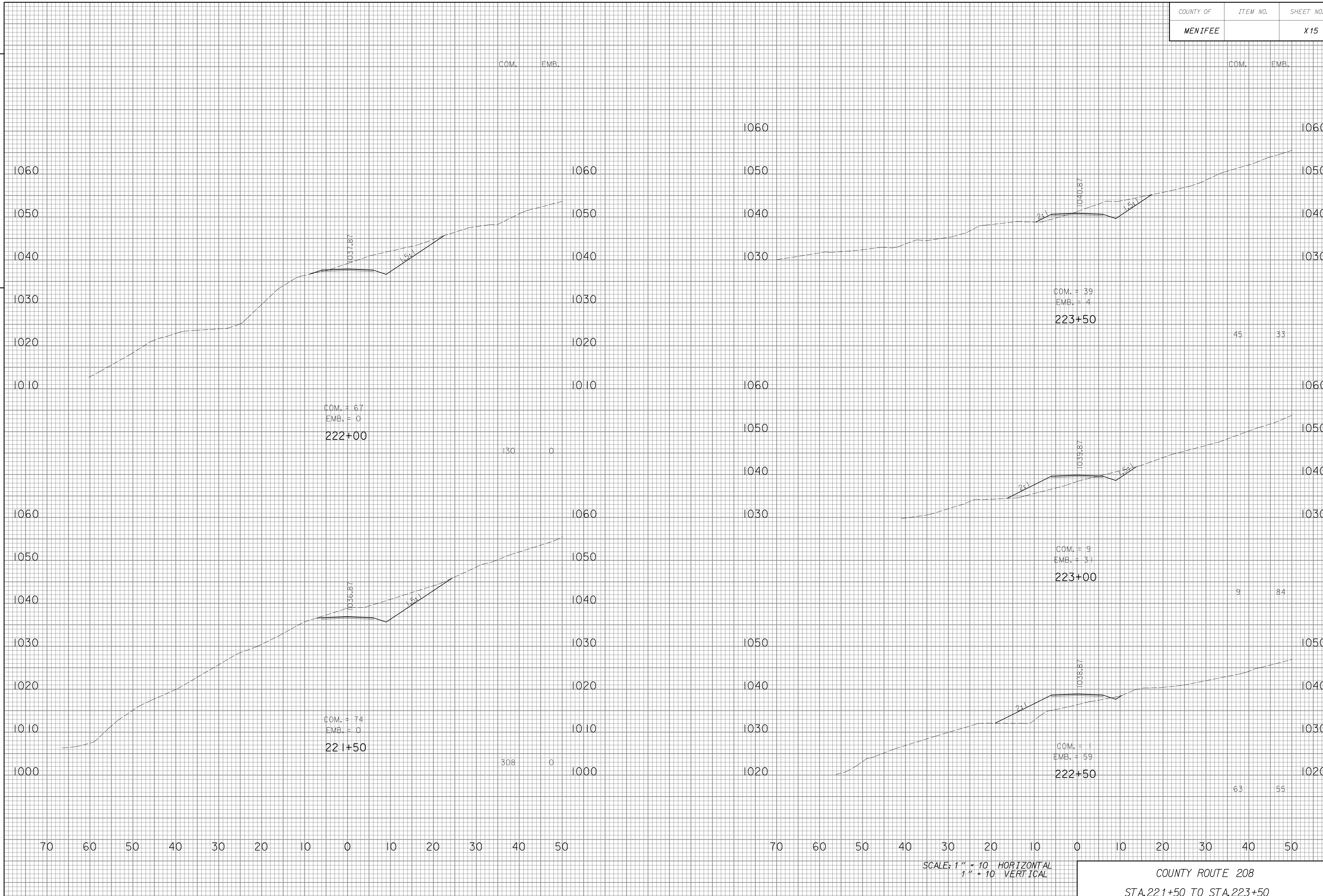
PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208
STA.219+50 TO STA.221+00

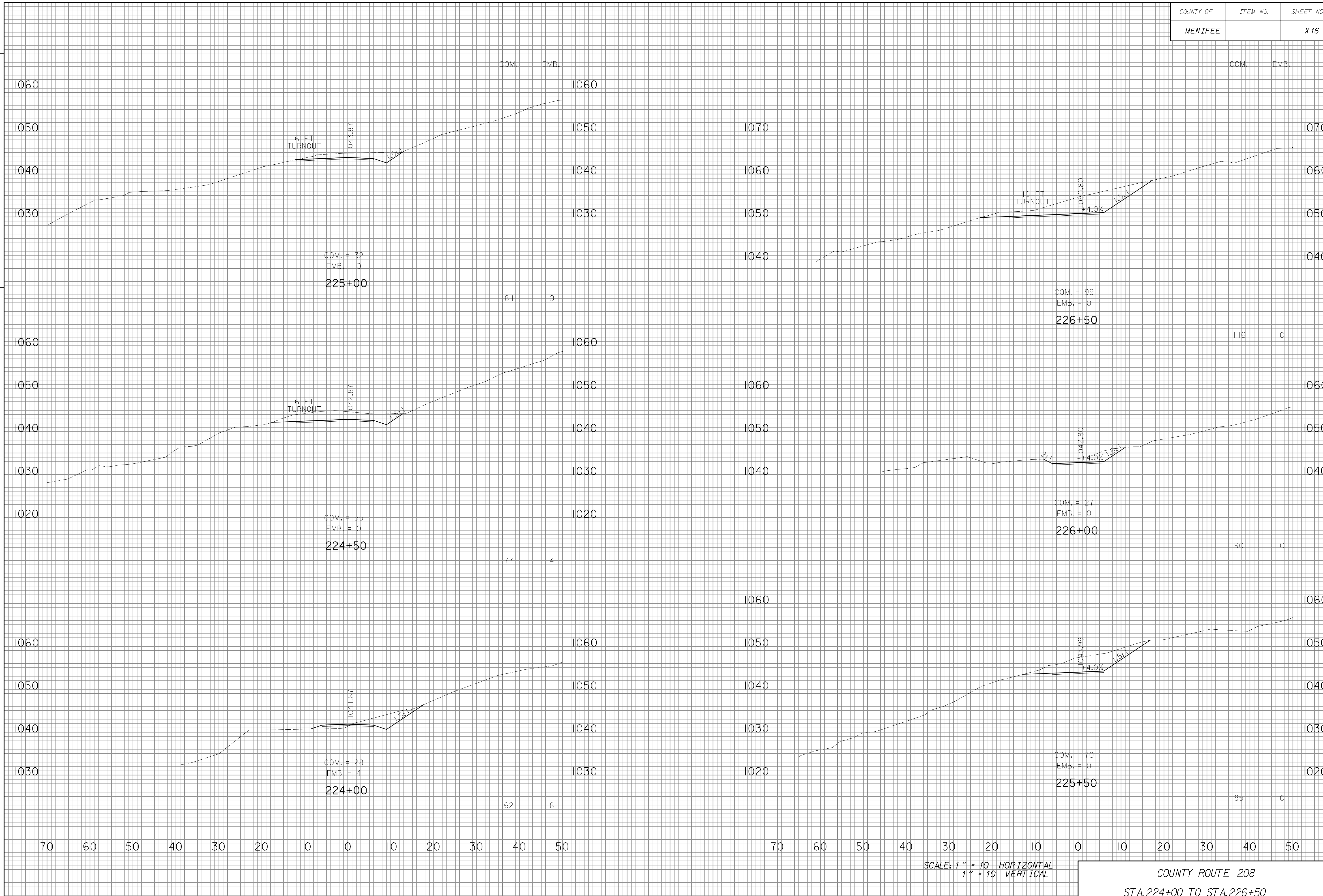
USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______



USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

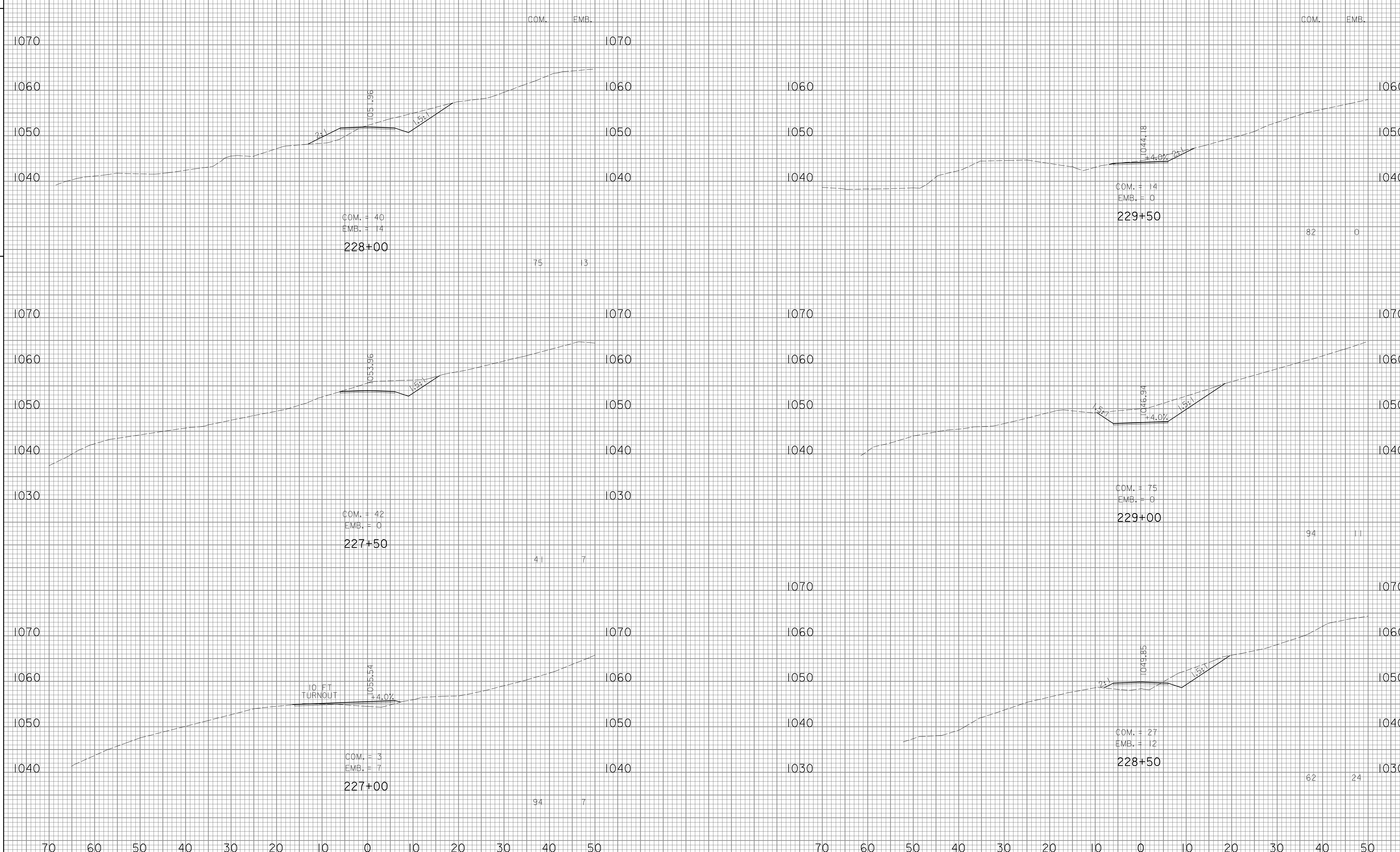
PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______



USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X17

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

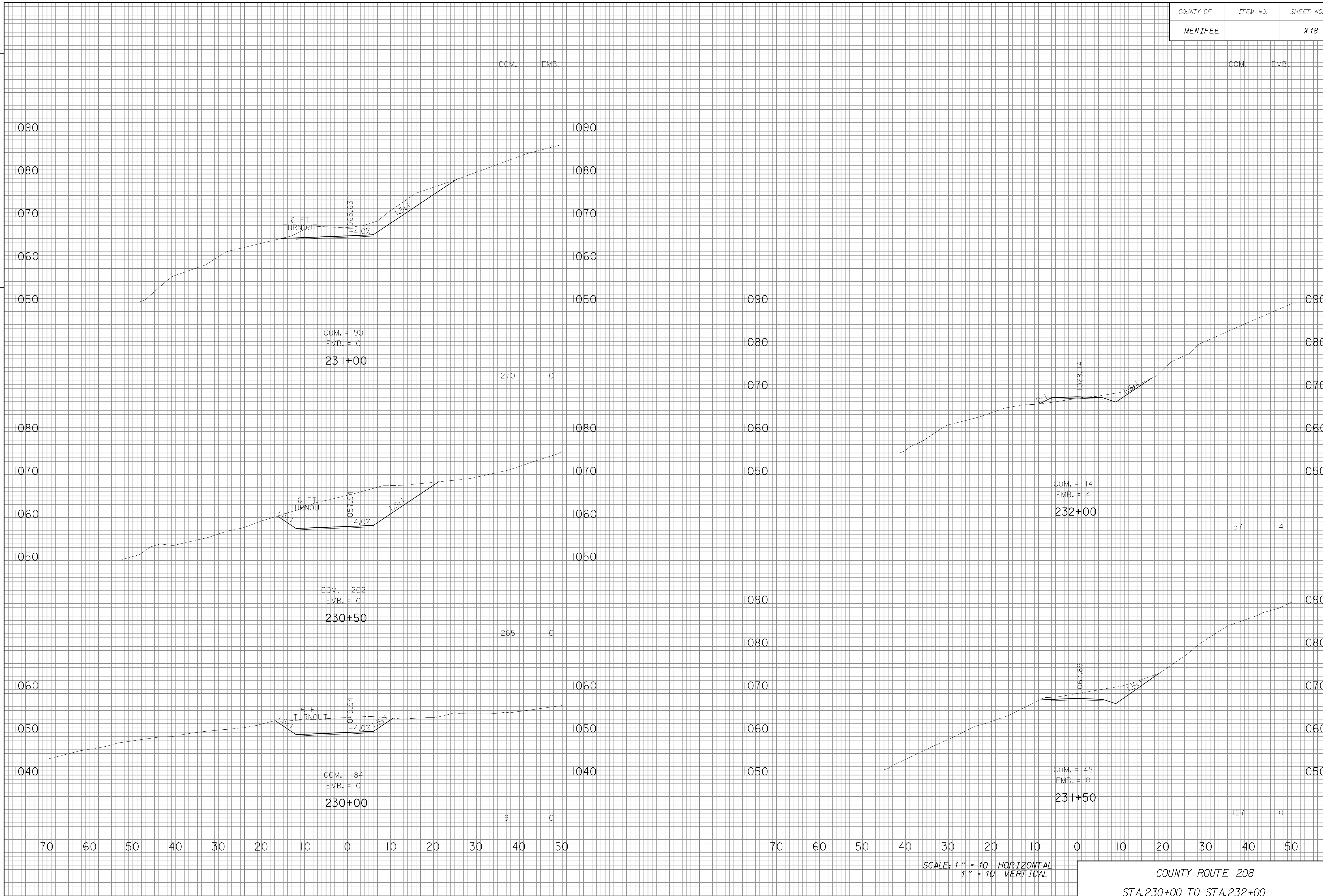


SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.227+00 TO STA.229+50

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:



PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X19

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208
STA.232+50 TO STA.234+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X20

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208
STA.234+50 TO STA.236+00

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X21

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.236+50 TO STA.239+00

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X22

PREPARED BY ________ DATE ________
CHECKED BY ________ DATE ________
APPROVED BY ________ DATE ________

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.239+50 TO STA.241+50

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X23

PREPARED BY ____ DATE ____
CHECKED BY ____ DATE ____
APPROVED BY ____ DATE ____

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.242+00 TO STA.244+50

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X24

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.245+00 TO STA.247+00

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

COUNTY OF	ITEM NO.	SHEET NO.
MENIFEE		X25

PREPARED BY ______ DATE ______
CHECKED BY ______ DATE ______
APPROVED BY ______ DATE ______

COM. EMB.

COM. EMB.

USER: $$$$USER$$$$
DATE: $$$$DATE$$$$
FILE NAME: $$$design$file$specification$$$$
E-SHEET NAME:

SCALE: 1" = 10 HORIZONTAL
1" = 10 VERTICAL

COUNTY ROUTE 208

STA.247+50 TO STA.248+70